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ABSTRACT

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning, in cooperation with the Committee of Ontario Deans of Engineering (CODE) conducted a planning assessment for doctoral work in electrical engineering. Emphasis is placed on the supply and demand of doctorates in electrical engineering; factors to consider related to the doctoral programs in electrical engineering; evaluation of the doctoral program in electrical engineering in Ontario Universities; and recommendations. Information is given on electrical engineering programs at Carleton University, McMaster University, University of Ottawa, Queen's University, University of Toronto, University of Waterloo, University of Western Ontario, and the University of Windsor. For a study on chemical engineering, see HE 005 862. (MJM)

Council of Ontario Universities

Perspectives and Plans for Graduate Studies

11
Engineering
B. Electrical Engineering
1974

Advisory Committee on Academic Planning

Ontario Council on Graduate Studies

ED 095796

Council of Ontario Universities
Conseil des Universités de l'ontario

PERSPECTIVES AND PLANS FOR GRADUATE STUDIES

11. ENGINEERING 1974*

B. ELECTRICAL ENGINEERING

Advisory Committee on Academic Planning
Ontario Council on Graduate Studies
74-14

* The status of this report is given in Item 2 of the statement of principles, on page 1.

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ENGINEERING 1974

B: Electrical Engineering

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This report deals with a planning study of doctoral work in engineering, which was conducted in several portions corresponding to the various disciplines within engineering. The report is in six volumes. Volume A deals with chemical engineering, B with electrical engineering, C with metallurgical and materials engineering, D with mechanical engineering, E with industrial engineering, and F with civil engineering. Each volume contains the COU and ACAP reports for engineering as a whole together with the consultants' report and other material appropriate to one of the disciplines. The COU report will be in three parts: Part I dealing with the recommendations approved in June 1974 and dealing with most of the fields, Parts II and III to appear later dealing with mechanical and industrial engineering, and with civil engineering respectively. This volume, printed in the summer of 1974, contains only Part I.

FOREWORD

As a consequence of a study of engineering education in Ontario (described in more detail in the subsequent ACAP report) the Council of Ontario Universities called for a planning assessment of PhD programmes in engineering to be carried out by ACAP in cooperation with CODE.

The Advisory Committee on Academic Planning (ACAP), as presently constituted, was established by the Ontario Council on Graduate Studies at the request of the Council of Ontario Universities in January, 1971. The Advisory Committee's terms of reference were directed broadly toward the effective planning and rationalization of long-term graduate development in Ontario's universities both at the level of individual disciplines and at a more general level. The Advisory Committee's activities are based on the premise that graduate work is the one area of university activity in which specialization among universities, cooperative arrangements and comprehensive planning are most necessary.

The disciplinary planning process involves a discipline group composed of one representative from each university with an interest in graduate work in the planning area. In the case of engineering, CODE was also involved in a way described in the ACAP report. The discipline group assists in defining the precise academic boundaries of each study, and prepares a commentary on the consultants' report.

The final decision on consultants for the planning study is made by ACAP. The consultants are requested to make recommendations on programmes to be offered in Ontario, desirable and/or likely enrolments, the division of responsibility for programmes among universities, and the desirable extent of collaboration with related disciplines.

While the consultants' report is the single largest element in the final report on the planning study, ACAP considers the statement of each university's forward plans to be most significant. These forward plans are usually outlined prior to the planning study, and are used as a basis for comments from the universities concerned on the consultants' report.

On receipt of the consultants' report, and comments on it from the disicpline group and the universities, ACAP begins work on its own recommendations for submission directly to the Council of Ontario Universities. COU considers the input from all sources, and prepares the position of the Ontario university community.

The following report is one of a series of disciplinary planning studies carried out by the Advisory Committee on Academic Planning and to be published by the Council of Ontario Universities. The emphasis of the report is on forward planning, and it is hoped that the implementation of COU's recommendations will help to ensure the more ordered growth and development of graduate studies in Ontario's universities.

Council of Ontario Universities
Conseil des Universités de l'Ontario

Report and Recommendations concerning Doctoral Studies in Engineering - Part I

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning, in cooperation with the Committee of Ontario Deans of Engineering, has conducted a planning assessment for doctoral work in engineering. This arose from the need to re-examine the recommendations concerning PhD work which appeared in Ring of Iron. The background to the study, the procedures followed and the planning techniques used are described in the ACAP report and are not repeated here. The resultant report from ACAP is attached together with the consultants' reports, the comments by the discipline groups, the comments of the individual universities, and the comments of CODE. It is important for the reader to read the attachments in order to understand the recommendations in this Report from COU. COU will issue subsequent parts to this report dealing with mechanical, industrial and civil engineering.

The Council received the ACAP report and supporting documentation on April 11, 1974. The content of the ACAP document was debated on April 11, on May 3, and on June 7, 1974. As a result of these discussions this Report and Recommendations was prepared and approved by the Council on June 7, 1974. The report is addressed to the Ontario Council on University Affairs and the universities of Ontario.

The following principles have been adopted and will apply to this and all other COU Reports arising out of assessments.

1. Discipline assessments by ACAP should form the basis for planning by the universities of their development of graduate studies, particularly PhD programmes. On the basis of these assessments, COU should make its own recommendations on currently embargoed programmes. Each university must retain the freedom and responsibility to plan and implement its own academic development. However, the universities in embarking on a cooperative planning process have signalled their intentions of cooperating with the COU recommendations.

2. Universities generally plan their emphases in graduate study on the bases of related departments, not of single departments. Initially the sequential nature of the discipline planning assessments makes this difficult. However, by the summer of 1974 there will have been assessments of most of the social sciences, all of the physical sciences, engineering doctoral work, and a number of professional areas. On the information and recommendations then available, each university should be able to make decisions concerning its support of graduate programmes in these areas. Amendments to university responses to the individual discipline planning assessments may then be made in the wider context of a group of related disciplines and amendments to COU's original Reports on an individual discipline may be required.

3. The first concern in planning is to review the quality of graduate opportunities and of students in Ontario universities and to make judgements about how to proceed or not proceed based on quality considerations. The procedures have made use of highly qualified independent consultants who have no direct interest in the universities in Ontario. Accordingly, COU feels bound to accept their judgements about quality where they are stated clearly unless unconvinced that their conclusions about quality are consistent with their evidence. COU's recommendations in the case of programmes which are of unsatisfactory or questionable quality will call for discontinuation or the carrying out of an appraisal, if the continuation of the programme is not crucial to the province's offerings. In some cases, however, there may be a particular need for the programme and the appropriate recommendation will be to strengthen it, with an appraisal following that action. It is also possible that if there were found to be too large a number of broadly-based programmes there could be a recommendation to discontinue the weakest; in this case, an appraisal for a more limited programme might be relevant.

4. A second consideration is the scope of opportunities for graduate work in the discipline. Do the Ontario programmes together offer a satisfactory coverage of the main divisions of the discipline?

5. Numbers of students to be planned for will depend on the likely number of applicants of high quality and in some cases may relate to an estimate of society's needs. Such estimates may be reasonably reliable in some cases and not in others. If the plans of the universities appear to be consistent with the likely number of well-qualified applicants and there is either no satisfactory basis for estimating needs or there is no inconsistency between a reasonable estimate of need and the universities' plans, then COU will take note of the facts without making recommendations on the subject of numbers.

   If the numbers being planned for by the universities are grossly out of line with the anticipated total of well-qualified students, or a reliable estimate of needs, COU will make appropriate corrective recommendations. Depending on the circumstances, these may call for a change in the total numbers to be planned for and indications of which institutions should increase, decrease, or discontinue. The recommendations in serious cases may need to specify departmental figures for each university for a time. If the numbers being planned for are insufficient, the recommendations may call for expansion, or new programmes, and may have implications for both operating and capital costs.

   Unless there are exceptional circumstances, the recommendations concerning enrolment will not call for a university to refuse admission to any well-qualified student who wishes to work in a field in which that university offers a programme and in which it has the capacity to accommodate the student.

6. The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design.

7. Universities will be expected to notify COU if they intend to depart from the COU Report in any way which they believe might have a significant bearing on the provincial plan.

8. Appraisals arising as the result of assessments are to be based on the standards but not necessarily the scope of the acceptable programmes in the province.

General observations concerning engineering doctoral work

1. Ontario is unlikely to over-produce engineering PhD's in the next five years. However, the student body contains too large a proportion of non-Canadians. Qualified Canadians should be encouraged to seek the engineering PhD.

2. Doctoral students should be selected on the basis of high academic standing and research potential.

3. "Inbreeding" is a problem, with many students obtaining three degrees from one university.

4. Faculty members, whether or not engaged with doctoral students, should have the facilities and opportunities to engage in research and in work with industry.

5. The scope for inter-university and university-industry cooperation is considerable and should be exploited.

6. The quality and state of development of the Ontario doctoral programmes are variable. Some are very good and have gained international recognition.

7. Some universities are organizing (or reorganizing) doctoral study on a division of specialization other than that provided by the "traditional" engineering departments. In two of the smaller faculties this is a central factor in the planning, but increasing cross-departmental activity is also in evidence elsewhere.

Actions by COU

1. COU has abandoned a planning number of 450 doctoral students and advises the universities to plan on the assumption that the doctoral enrolment will remain roughly constant for the next five years. Although there is a need for engineers with doctorates in Ontario, graduate student enrolment will level off due to a lack of top quality students. Canadians must be attracted in increasing numbers in order to maintain enrolment at the present level.

2. COU requests that CODE report annually to COU on enrolment and employment opportunities.

3. COU requests that ACAP arrange for each engineering discipline group:
(1) to monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students (to ACAP for transmission to COU);

(2) to report annually to ACAP on the universities previously attended by the newly admitted graduate students of each department.

4. COU requests CODE, after consultation with the discipline groups, to develop proposals for collective methods of making information on graduate work in all Ontario universities readily available to the engineering students, and to inform ACAP of the action taken.

5. COU requests OCGS to examine existing university guidelines on part-time doctoral work and its supervision.

6. COU request that ACAP arrange for an annual report to OCGS from each university on the time taken for each graduating student to complete his doctoral studies.

7. COU requests ACAP to examine the available documentation on civil engineering, to reach its own judgements on the basis for a report, after soliciting assistance from the discipline group and the universities, and to prepare its report to COU containing recommendations for the future of civil engineering doctoral work. This should be submitted by December 31, 1974.

8. COU requests that ACAP arrange for the metallurgical and materials engineering discipline group to present a report to ACAP on university actions taken to correct identified weakness in certain fields of study.

Recommendations

It is recommended that:

1. Universities, CODE and discipline groups take steps to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

2. The universities attempt to maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

3. The universities, the provincial government, and granting agencies examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined.

4. All doctoral thesis examining committees have an examiner external to the university.

5. At present, there not be any specific engineering doctoral part-time programmes but rather that part-time or non-resident doctoral work be done by individual arrangement. Experimentation in methods of carrying on part-time work is to be encouraged and might lead in future to the creation of specific part-time programmes. It is also recommended that the research topic of any student accepted on a part-time basis be in a field in which the professors in the department have expertise.

University Recommendations

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

It is recommended that:

6. The University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. If a favourable appraisal is not obtained by the end of October, 1976, admission of new students should then be suspended.

7. The University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained.

8. The involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the university begin doctoral work in agricultural engineering at a time in accordance with the university's plans, subject to normal appraisal procedures.

Chemical Engineering

This section deals with doctoral work in chemical engineering at McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

9. The departments consider grouping their research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

10. McMaster University continue its doctoral work in chemical engineering according to its plans.

11. The University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

12. Queen's University re-evaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the university considers appropriate. If a favourable appraisal has not been received by October, 1976, enrolment of new students then be suspended.

13. The University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to the desirable mobility of its bachelor's graduates for graduate work elsewhere and to the desirability of grouping of research areas. The University of Toronto is requested to report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

14. The University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

The consultants' report is unfortunately inadequate for planning purposes.

It is recommended that:

15. The embargo on the funding of any new programmes in civil engineering continue until COU has accepted a report from ACAP dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted by ACAP by December 31, 1974.

Electrical Engineering

This section deals with doctoral work in electrical engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

The discipline group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

17. Carleton University continue its doctoral work in electrical engineering according to its plans.

18. McMaster University continue its doctoral work in electrical engineering according to its plans.

19. The University of Ottawa plan the reorganization of its doctoral programme in electrical engineering and put forward the programme for appraisal. If a favourable appraisal has not been obtained by the end of the fall term 1976, admission of new students should cease. In the meantime, enrolment of new students should be restricted to the digital communications systems and large-scale systems fields.

20. Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields should be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

21. The University of Toronto continue its doctoral work in electrical engineering according to its plans.

22. The University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Metallurgical and Materials Engineering

This section deals with doctoral work in metallurgical and materials engineering at McMaster, Queen's, Toronto and Waterloo.

It is recommended that:

23. The universities take steps to increase the activity in the ceramics, glasses, and polymer fields of study in the province.

24. McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and make a report to COU through ACAP in the fall of 1975 on the following suggestions for improvement:

    a) recruitment of students with physics and chemistry backgrounds
    b) strengthening of the extractive metallurgy faculty
    c) collaboration with the University of Toronto

25. Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors from other departments. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish

to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

26. The University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto consider broadening the programmes and it is requested that the university report to COU through ACAP by September, 1975, on any progress made in this direction.

27. The University of Waterloo continue its doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

It is recommended that:

28. Queen's University continue its doctoral work in accordance with its plans.

General

It is recommended that:

29. In view of the acceptance of these recommendations by the Council of Ontario Universities and the completion of Part I of this planning assessment, the Ontario Council on University Affairs request the Minister to remove the embargo on doctoral work in Engineering (except for Mechanical, Industrial and Civil Engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo), in accordance with the original announcement of the Minister that new graduate programmes would be embargoed until, for each discipline, a planning study has been conducted.

Notes concerning the recommendations

Re: Recommendations 1, 2, and 3

The background to these important recommendations appears on pages 13 and 14 of the ACAP Report.

Re: Recommendation 7

Presumably the programmes submitted for appraisal will be the three divisional programmes which are replacing the departmental programmes.

Re: Recommendation 16

Other engineering discipline groups may also find this a valuable suggestion.

Re: Recommendation 19

This differs from the recommendation in the ACAP Report because the University subsequently decided to carry out a re-assessment of the future direction of the department.

Re: Recommendation 25

Queen's has reported to COU its intention to enlarge its programme in extractive metallurgy.

June 7, 1974.

ADVISORY COMMITTEE ON ACADEMIC PLANNING

ONTARIO COUNCIL ON GRADUATE STUDIES

REPORT TO THE COUNCIL OF ONTARIO UNIVERSITIES
ON
ENGINEERING DOCTORAL PLANNING ASSESSMENTS

JUNE 7, 1974

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I. RECOMMENDATIONS

General Recommendations

C1

It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU on enrolment and employment opportunities.

C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

C6

It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

C7

It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

C8

It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

C9

It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

University Recommendations

C10

It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

C11

It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained by that date.

C12

It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the University's plans, subject to normal appraisal procedures.

Chemical Engineering

C13

It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

C14

It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

C15

It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

C16

It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

C17

It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

C18

It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

C19

It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

Electrical Engineering

C20

It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

C21

It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

C22

It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

C23

It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

C24

It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

C25

It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

C26

It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Mechanical Engineering

C27

It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

C28

It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

C29

It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

C30

It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

Metallurgical and Materials Engineering

C31

It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these recommendations.

C32

It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:

a. recruitment of students with physics and chemistry backgrounds

b. strengthening of the extractive metallurgy faculty

c. collaboration with Toronto.

C33

It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

C34

It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975, on any progress made in this direction.

C35

It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

C36

It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

Industrial Engineering and Systems Design

C37

It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

C38

It is recommended that the University of Waterloo continue its doctoral programme in systems design.

II. BACKGROUND AND PROCEDURE

In June, 1968, the Committee of Presidents of the Universities of Ontario, after a meeting with the chairman of the Committee on University Affairs, decided that a comprehensive review of engineering education in Ontario should be undertaken. The Committee of Ontario Deans of Engineering (CODE) was requested to draw up plans for such a study, and this proposal was approved by the Committee of Presidents on November 15, 1968. The objective was to create a master plan which could be used as a guide for rational growth of engineering education during the 1970's. Such a plan should endeavour to provide for the highest attainable quality, the best use of resources, opportunity for innovation, and maximum freedom of choice for students.

This study culminated in the report Ring of Iron prepared by a commission chaired by Philip Lapp.

The report was received by the Committee of Presidents in January, 1971. A process of review of the report's recommendations was established, CODE prepared a brief based on statements of views submitted by each university concerned and by each Faculty of Engineering. Briefs were prepared also by the Ontario Council on Graduate Studies (OCGS) and the Association of Professional Engineers of Ontario. On October 5, 1971, the Council of Ontario Universities (COU) considered Ring of Iron and the briefs and prepared a statement of recommendations to the universities and to CUA.

COU accepted a number of the Lapp recommendations without change, others with amendments and rejected some. Broadly speaking, the recommendations to do with undergraduate matters were accepted or modified slightly. The graduate area of the report was more controversial, but here also some recommendations were accepted. The most significant of the recommendations concerning graduate study, as approved by COU, are:

> "The criteria of acceptability of graduate degrees in engineering should be recast in order that a thesis based on design or systems synthesis may be suitably assessed. This could involve the establishment of a new degree at the doctorate level."

> "Both universities and industries should recognize joint appointments as part of the career structure of their senior staff; these appointments should be increased as far as possible..... By this we understand a system of part-time appointments."

> "Over the next two years the estimated graduate enrolment of 2,000 full-time equivalent students for 1970-71 be reduced by 17%, after which graduate enrolment should be limited to a number equal to the previous year's bachelor graduations. The enrolment figure applies to the engineering departments as identifed in Ring of Iron".

"The recommendation that the number of PhD students enrolled be reduced to 450 per year is fully supported by all groups including COU. However, COU, along with CODE and OCGS, recommends that the figure of 450 be the target for 1974-75, rather than for 1973-74, for reasons related to avoiding large fluctuations in enrolment as explained in the OCGS critique."

"The Lapp report recommends specific numbers of PhD enrollees for each of the universities including discontinuance of the PhD enrolment in certain universities. COU feels that the reasons for the numbers chosen or for the elimination of certain doctorate programmes are not fully documented in the Lapp report. COU also agrees with CODE and OCGS that attention must be given to the numbers of doctorate enrollees by discipline as well as by university. For these reasons COU recommends that for the year 1972-73 doctorate enrolment be reduced in each university below the projected figure for 1971-72 by a pro rata percentage in order to provide 612 doctoral candidates (the number required to achieve the target of 450 in 1974-75). Preliminary acceptance of the OCGS method for reducing PhD enrolment (by limiting new PhD enrolments to achieve a total system number of 450 by 1974-75) is based on plans for discipline planning assessments respecting PhD programs to be initiated immediately and completed as rapidly as possible. Such assessments will be carried out by ACAP in cooperation with CODE; they are to incorporate capability, demand and quality correlates, and are to be used to provide specific recommendations on changes for the total PhD enrolment, and for the division of the enrolment amongst universities and amongst disciplines. The assessments are to incorporate a review of the effects of the pro rata reductions in 1972-73, and to recommend a mechanism for continuing review of PhD enrolments."

On receipt of this instruction from COU, ACAP and CODE established a liasion committee (Ayers, Dillon, Ham, Johnson, Shemilt, McIntosh, Preston) which drafted procedures for the assessments. It may be noted that the committee considered a model in which the assessments were based, not on the five traditional departments found in engineering faculties, but rather on interdepartmental areas of research; the practical difficulties of conducting the assessments led the committee to recommend the five-fold subdivision actually used.

The procedure developed in this way was approved by ACAP on March 17, 1972, and by COU on April 7. The procedure (except for minor data amendments) is that in Appendix D to this report. In writing to indicate its approval CODE expressed their understanding that two objectives would be met:

"1. To provide a rational basis for doctoral work in engineering and for confirming or modifying the limitation on enrolment suggested by Lapp.

2. To conduct a really effective assessment of the quality of our current doctoral programmes."

CODE went on to emphasize the need of adequate resources to obtain the best consultants.

In order to begin the planning assessments, the ACAP/CODE liasion committee called a meeting of members of the five Discipline Groups (Chemical, Civil, Electrical, Mechanical, and Metallurgical Engineering). This meeting on April 12, 1972, indicated a good deal of faculty resistance to the conduct of the planning assessments and uneasiness about some perceptions of some aspects of the approved procedures. This resulted in a delay in mounting the assessment. CODE suggested a Coordinating Task Force, consisting of two members of CODE, the chairman of each Discipline Group, and a member of ACAP could review the procedures. ACAP advised COU to agree to this request and the COU executive did so on June 9, 1972. This Task Force held meetings on June 29, July 27, September 1, September 25, November 29, 1972 and March 19, 1973. It suggested two slight additions to the procedures as approved earlier by COU. These were approved by COU on September 25, 1972. The Task Force also produced a document clarifying some aspects of the procedure in detail, and a statement of some educational philosophies concerning doctoral study. These documents are referred to in the terms of reference of the consultants. The Task Force also advised ACAP (and so did universities) on how to take into account for planning purposes those doctoral programmes in Faculties of Engineering which did not fall obviously into the fields covered by one of the five consulting teams. It was eventually decided that:

a) both the metallurgy and the mechanical engineering consultants would be asked to consider the metallurgical work within the Department of Mechanical Engineering at Waterloo

b) no advice from external consultants would be sought on the doctoral programme in mining engineering at Queen's

c) a small-scale "planning assessment" involving two consultants would be carried out in industrial engineering and systems design

d) in view of the fact that all current doctoral students at Guelph are in hydrology and that the field of agricultural engineering is also proposed, the civil engineering consultants would be asked to consider the Guelph doctoral work, with the understanding that if they so wished ACAP would facilitate a consultation for them with someone in a department of agricultural engineering

e) the mechanical engineering consultants be asked to consider the doctoral work at the University of Toronto Institute of Aerospace Studies and in aeronautical engineering at Carleton, with the request that they consult also with another of the ACAP consultants (on the Electrical Engineering team) who had expertise in some of the UTIAS work outside mechanical engineering and also with an aerospace specialist

f) advice on the future plans of the Department of Management Science at Waterloo would be sought from the consultants in the planning assessment in Administration, Business and Management Science, with a comment also provided by the consultants on industrial engineering.

g) no special arrangements were needed in connection with biomedical engineering at Toronto since the corresponding institute has no graduate programme of its own, and the future doctoral plans are covered in the statements from each of the associated departments.

Item f will be dealt with in a later report. The remainder are covered in this report. The mechanical engineering consultants informed ACAP that they did not require the assistance suggested in item e.

In October, 1972, CODE proposed that a study be carried out, under the aegis of the newly established Canadian Engineering Manpower Council, and with financial support from a number of agencies, in order to make recommendations about "supply and demand" for engineering doctorates. This would be expected to be of great value to the planning assessments. ACAP agreed to this suggestion, provided funds towards the costs, and incorporated reference to the study into the instructions for the consultants. In the event, the study proved rather disappointing; it is discussed later in this report.

As a result of suggestions from the Discipline Groups and after receiving comments from the Coordinating Task Force and from CODE, ACAP agreed on consultants at its meetings of September 7-8, October 13 and December 18, 1972. The consultants who finally acted were:

<u>Chemical Engineering</u>:	Dean P. Grenier of Université Laval, Dean W. R. Marshall of the University of Wisconsin, Professor L. Yaffe of McGill University
<u>Civil Engineering</u>:	Professor W.W. Eckenfelder of Vanderbilt University Mr. B. V. Martin of Alan M. Voorhees and Associates Ltd., Professor G. G. Meyerhof of Nova Scotia Technical College, Dr. J. L. Boulet of Hydro-Quebec.
<u>Electrical Engineering</u>:	Professor A. D. Moore of the University of British Columbia, Professor M. E. Van Valkenberg of Princeton University, Dr. M. P. Bachynski of RCA Research Laboratories

<u>Mechanical Engineering</u>:	Professor H.W. Emmons of Harvard University, Dean G. Ford of the University of Alberta, Dr. R. D. Hiscocks of the National Research Council of Canada, Professor S.G. Mason of McGill University
<u>Metallurgical Engineering</u>:	Professor J.J. Jonas of McGill University, Professor T.B. King of the Massachusetts Institute of Technology, Professor W.S. Owen of Northwestern University and M.I.T., Dr. W.B. Lewis of Atomic Energy of Canada Ltd.

Brief curricula vitarum appear in Appendix G. In each case, the last named person played the role of a senior Canadian from outside the discipline.

The consultants held their first meetings at various dates in April and May, 1973 and in each case met with the appropriate Discipline Group, arranged the schedule of visits, discussed their character and had general discussion with the Discipline Group about the task before them. The visits took place in the two or three months following these meetings.

The consultant teams each submitted a draft report in September, which was the subject of oral discussion with the Discipline Group at a meeting within a few days of the receipt of the draft. Each consultant team then submitted its report. These reports were sent for comments to the universities, to the Discipline Groups and to CODE, each of which sent comments to ACAP at various dates in November, December and January.

A subcommittee of ACAP began consideration of the report to COU, before all the comments were in hand and continued its work through March, 1974, reporting regularly to ACAP and receiving instructions. Early in its meetings the committee identified some points on which further information and reactions were required. In particular, the need for fuller advice from the consultants. was felt in the cases of civil and mechanical engineering. Such further advice was sought, with results discussed in the relevant sections of this report. ACAP also thought some further information would be helpful in connection with three of the universities and arranged meetings with officials of these universities and members of ACAP.

This report is based on the consultants' reports, the data collected for the study, the universities' comments and supplementary material from some of them, the Discipline Groups' responses, and the other documentation referred to in the procedures and terms of reference. The report sets out recommendations for COU on doctoral work in engineering in Ontario for the next few years.

As is required, ACAP presents this report directly to COU. It has also been transmitted for information to OCGS, CODE, and the Discipline Groups.

III. GENERAL RECOMMENDATIONS

This section of the ACAP report contains recommendations that are of general concern to all of engineering. Some of these recommendations have been mentioned consistently in all the reports while others, although found in only one report, are applicable to all doctoral programmes.

Enrolment and Manpower Forecasts

In the summer of 1973, the Canadian Engineering Manpower Council released its report entitled Supply and Demand for Engineering Doctorates in Canada. This report was partly financed by ACAP and was given to all the consultant teams prior to their writing of their reports. It generally states that the supply of engineers in the next five years will exceed the demand.

A summary of the comments made by the engineering consultants concerning this report shows that they all independently disagree with the projections made in the CEMC report. They believe there has been no overproduction of PhDs to date and, in fact, there appears to be a shortage of metallurgical PhDs. Each team believes that the need for engineers will not decline, as predicted by CEMC but that the overall demand will continue and in actual fact, all but the civil engineering consultants believe it will increase.

ACAP had originally intended to publish a critique of the CEMC report. However, CODE in its repsonse to the engineering reports, Appendix H, has included a statement on this report covering all the points ACAP wished to make. ACAP's critique will not be reproduced, but we feel that the CEMC report is not an adequate basis for manpower planning in engineering. Since all the consultants agree that supply will not exceed demand but perhaps rather the reverse, the question of supply of qualified students must be studied. The main problem will be attracting Canadians into engineering graduate work. In 1972-73, of the 518 F.T. engineering PhDs, 28.6% were Canadian, 53.3% were landed immigrants and the remaining 18.1% were on student visas.

Changes in the immigration regulations make it harder to become a landed immigrant. Since one can no longer apply for landed immigrant status while in Canada, those that come on student visas will presumably return to their homelands. Coupled with this is another new regulation that a teaching assistantship is no longer classified as a job, thus making it harder to obtain landed immigrant status. Consequently, ACAP feels that the percentage of landed immigrants in graduate work will drop while the number of students visas will increase. Financial support for people on student visas is scarce. There are very few scholarships or bursaries open to them but in engineering they may be supported from contract funds. In any case, there will be funds for only a few. Although Canada has a role to play in providing advanced technical education for the underpriviledged countries of the world, this should be kept to a reasonable level and should not exceed 30% of engineering doctoral enrolments.

CODE, on page H-9 of its response, states that "unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline". There are suggestions that student stipends be increased. We remain unconvinced that stipends need be any higher in engineering than in any other field, but there is one exception and this is that people with substantial professional experience returning to graduate study should be supported at a higher level.

ACAP is inclined to agree with the University of Waterloo's comment, page C-29 in its response to the chemical engineering report, that the best way of attracting Canadian students is a "change in the general atmosphere surrounding doctoral work in engineering in this country and to convince the brightest young Canadian students that there are challenging opportunities for advanced work in Canadian industry". Increased dialogue with industry as well as up-to-date information on jobs available would make the employment picture brighter and more alluring to prospective Canadian graduate students especially if the number of industrial scholarships were increased and more interaction were seen to be taking place between industry and university.

This dialogue with industry is needed to ensure that more Canadians continue in graduate work. If industry indeed has a place for the master's or doctorate in engineering, more must be done to encourage good students to stay in university instead of taking a job after the bachelor's degree. Industry in its hiring policies can encourage this.

The chemical engineering consultants recommend that the universities should endeavour to develop entrepreneurship in students. They feel "this is a quality so badly needed at present in Canada".

It does not seem as though Ontario will overproduce engineering PhDs in the next five years. The question is rather whether there will be enough qualified students. In view of this possible shortage, the following recommendations are made by ACAP.

Recommendation C1

> It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU on enrolment and employment opportunities.

Recommendation C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

Recommendation C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

Recommendation C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

Admissions

ACAP does not support the view held by the electrical engineering consultants, namely that admitted doctoral candidates should have first class standing and proven research ability. Many students who graduate with high second class honours have become excellent research engineers. The usual minimum standard of the better departments is a high B and all the consultants agree that high standards of admissions prevail generally.

Recommendation C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

CODE agrees with ACAP on the annual post facto analysis of admission practices (page H-3). The chemical engineering consultants have suggested "that should it be found that students have been accepted who, in the opinion of the committee, do not fulfill the minimum requirements, the committee advise COU that a recommendation be made to the requisite authority suggesting no BIU be awarded for that student". ACAP does not feel this to be necessary at the present since regular reporting by the Discipline Group should exert considerable pressure if an institution repeatedly admits students of a low standard.

Undergraduate-Graduate Relationship

Some consultants assert that each department should provide all levels of study: bachelor's, master's and doctoral. Some go so far as to say that a doctoral programme in each department is essential. CODE, on the other hand, feels that what is important for a good undergraduate programme is research and professional activity by the faculty, and that this can be carried forward without graduate students, although at present the research activity is most easily carried on through graduate programmes (page H-3). ACAP agrees with the position stated by CODE and indeed applies it to all subjects, not only engineering, but with the comment that in many fields it is not difficult for a professor to be active in research without having graduate students. We would point out that the other position would imply that no department should exist unless it can operate an effective doctoral programme, a view which we find impossible to accept. The absence of sufficient research and professional activity by professors would raise questions about the quality of a department and hence of its undergraduate offerings, whether or not it offered doctoral work.

Thesis Quality

Recommendation C6

> It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

Since some of the consultants have made reference to the make-up of examining committees ACAP would wish to endorse this practice of including an external examiner.

Critical Size

We agree with CODE that there must be sufficient range of interaction for the student and that the judgement as to the presence of this interaction must include consideration of the involvement of persons outside the student's department and should include post-doctoral fellows and research associates as well as students. Although these planning assessments were vertical, as CODE suggests, each department was asked to state the extent of this interaction in its university. We agree that there is no *a priori* reason why a small school cannot provide as satisfactory an environment as can a large school. The question is not one of principle, but one of fact: does university A in fact provide the requisite environment for interaction for the average student in its department X?

Most of the consultants considered this question carefully and made specific comments but others provide no evidence that they examined the matter in any of the universities. While most agree that successful programmes can exist in small as well as large departments, the consultants still expect a wide range of courses to be offered. This in turn requires a certain number of students to make the courses economically feasible and academically stimulating.

Mobility of Students

The chemical engineering consultants are concerned about the lack of mobility of engineering students. They do not consider it a good educational experience to study for all three degrees, the bachelor's, the master's and the doctorate, at the same university. Such a programme leads to inbreeding and sameness and precludes any chance for the student to come in contact with different faculty, students, milieu and methods.

One sometimes hears a professor accept this in theory, but then say that in practice the student must not be prevented from going to the university of his choice. That view appears to us to be correct, provided the student's choice is made on sound academic grounds, based on good information of the opportunities that are available to him, and taking account, of course, of the undesirable aspects of remaining in one university.

Recommendation C7

> It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

Part-time Programmes

In 1972-73, 18% of the doctoral students studying engineering were doing so on a part-time basis. 65% of these students were Canadians and another 32.5% were landed immigrants. It would appear that these part-time programmes are being used by the profession to upgrade the skills and knowledge of its practising engineers.

The consultants seem divided on the issue of part-time programmes, some saying "such undertakings should be rarely encouraged" and others, "full encouragement should be given to part-time doctoral programmes." ACAP feels that there is a place for the part-time programme and that careful attention should be devoted to designing part-time programmes, bearing in mind the strengths of the departments. One of the dangers sometimes noted is that students become involved, under a part-time supervisor, in a project in an area in which the full-time staff has limited expertise; this is not recommended.

Recommendation C8

It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

Cooperation

One of the main points that all the consultants agree upon is the need for increased cooperation both within and between universities. The chemical engineering consultants found a need for increased interaction between the engineers and the pure science faculties. Some of the other consultants felt the need for more communication and cooperation between the universities and industry and government. Lastly, more effective use could be made of the resources in the province if the universities themselves joined together in some form of cooperative endeavour. CODE endorses this last point quite strongly in its response, page H-4. Sharing of equipment, discipline meetings and an interchange of credits for graduate courses are a few of the methods listed by CODE that are to be encouraged on the way to making this cooperation a meaningful and workable venture. ACAP concurs with the statements made by the consultants and CODE and strongly supports their implementation.

ACAP intends to request that each Discipline Group report regularly to ACAP on interuniversity cooperative arrangements.

Faculty

Two sets of consultants found enough disquieting evidence in the engineering faculties of the province to suggest that the requirements for a faculty member, eligible to supervise graduate students, should be reviewed and enforced. ACAP takes no position on whether or not there should be a separate Graduate Faculty, but there must be a mechanism to ensure that only those faculty with proven research ability and productivity supervise graduate students.

Since this concern has been mentioned in other assessments, ACAP feels it is time that OCGS conduct a review of this area.

Time to Reach Degree

The electrical engineering consultants were concerned about the length of time taken to obtain the PhD. As they pointed out, the average student at one university took 13-20 months longer to complete his doctorate than his counterpart at another university. As a whole, they found the average time of study to be excessive.

Recommendation C9

It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

IV. UNIVERSITY RECOMMENDATIONS

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

University of Western Ontario

The University of Western Ontario began to offer doctoral work in engineering in 1965. Since then, twenty PhDs in Engineering Science have been granted. From the beginning effort has been made to emphasise its interdisciplinary nature and there has been a limited number of areas in which the student may do his graduate training. At no point has a doctoral degree been given in the so called traditional fields of engineering.

There are seven main research areas in which a student may obtain a PhD in Engineering Science. They are 1. Geotechnical 2. Boundary Layer Wind Tunnel 3. Chemical and Biochemical Process Development and Design 4. Material Science 5. Systems 6. Applied Thermodynamics and 7. Applied Electrostatics. Environmental engineering aspects can be studied in all these research areas except Material Science.

Western's response to the collective engineering picture gives the 1973-74 enrolment as 29 F.T. and 15 P.T. doctoral students. In the additional data given to ACAP, 18 of the 37 current students' programme of study outlined were in the chemical engineering field, 8 were civil, 5 mechanical, and 3 each in electrical and material science.

The chemical engineering consultants have provided evidence of that programme's being of good quality. The systems research area depends heavily on chemical engineering. ACAP, therefore, concludes that the research areas Chemical and Biochemical Process Development and Design, and Systems are of satisfactory quality.

The metallurgical engineering consultants have recommended that the Material Science programme become a part of an interdisciplinary programme rather than an exclusively material science one. This was in part based on the fact that the group is small and spends most of its time teaching at the undergraduate level. They are "carrying a large programme for a group which is subcritical in size." From the additional material supplied by Western, there is little evidence of interdisciplinary activity for students who might be doing research in this area. ACAP concludes that this area should not be operating at the doctoral level.

The areas of mechanical engineering doctoral research work are subsumed under the main research area, Applied Thermodynamics. The consultants indicate that the doctoral research connected with heavy water is of good quality but they raise very serious questions about the doctoral work in acoustics. They feel this area should be restricted to work at the master's level.

The civil engineering consultants did not make comparative judgements, but from some of the phrases used to describe the Boundary Layer Wind Tunnel Laboratory such as "internationally known", ACAP has no reservations in recommending continuance of doctoral work in this research area, even though it appears to have little interaction with other groups. The civil engineering consultants told us nothing about the Geotechnical area and we, therefore, had difficulty in recommending a position to be taken with regard to this field.

The last research area, Applied Electrostatics, is the most difficult to assess. The electrical engineering consultants have recommended discontinuance of the doctoral programme. They feel the students are getting too narrow a training in electrical engineering. We observe, however, that the students are not considered to be studying for a PhD in electrical engineering, but rather for a general degree in engineering science. Although there are only a few faculty members in this area, they are internationally known. The main problem would, therefore, seem to be the extent to which the doctoral training in this area is of an interdisciplinary nature. From the data available to ACAP, we are unsure.

In the course of discussions with representatives of the University of Western Ontario, it became clear that the Faculty is involved in a thorough re-examination of its doctoral programme. It is committed to the concept of an engineering science PhD but is reconsidering the appropriate areas of research. While it is not entirely accepted by ACAP that all the activity is noticeably different from that in engineering departments elsewhere, we nevertheless believe that this intention of the Faculty should be encouraged. A corollary is that it must be very careful about the research areas in which it accepts PhD candidates; we have already commented on these and note the standard of quality seems variable.

These considerations have led us to formulate the following recommendation.

Recommendation C10

> It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

University of Windsor

Early in 1971, the Faculty of Applied Science at the University of Windsor began to examine the structure of graduate programmes within the Faculty in order to improve their operation, avoid needless and costly duplication of graduate course offerings and to attempt to create a greater cross-fertilization of research by involving faculty members from different engineering departments in various facets of a larger research plan. This examination led to the recommendation that Graduate Studies be operated on a divisional basis, with the seven undergraduate departments being consolidated under three graduate divisions, namely Engineering Process Design, Structures and Systems. The three divisions would each elect a chairman who would decide on course offerings and enrolment levels. The three chairmen, one elected member from each division, one graduate student and the Dean of Applied Science form a Coordinating Committee to oversee and coordinate the wishes of the Divisions. This plan was approved in Spring 1972 and is now being implemented.

Some of the traditional departments such as chemical and electrical fall completely in one division. All the rest are split between two as can be seen in the attached Table 1.

There are nine identifiable research areas, each of which have participating faculty from at least two of the old departments and these nine areas are in turn divided fairly equally among the three divisions.

The degrees awarded will retain the old titles, for example, a PhD in Chemical Engineering, but the interaction of the individual student with others in the Faculty will be greatly enhanced. Depending on his research topic, the student might take as many as half his courses from professors in other 'departments'.

The consultants' comments concerning Windsor vary, but a number of their reports imply some doubt or uncertainty concerning the relevant departmental programme, either with respect to the situation at the time of their visit, or in connection with its future direction. The chemical engineering consultants suggest that Windsor be reviewed in greater depth. The metallurgical engineering consultants recommend the integration of engineering materials faculty in the new divisional system. The mechanical engineering consultants call for more emphasis on master's work. In the case of electrical engineering the consultants indicate that good work is now being done in doctoral education in two fields, agree with the present plans for no significant growth in enrolment and for no expansion of fields, and go on to recommend a review after five years.

In view of these considerations ACAP feels the University of Windsor should be given time to produce a viable interdisciplinary system of doctoral engineering studies before that system is brought forward for appraisal. This appraisal would determine the level of quality in the new divisional system and whether or not significant interaction has been achieved between the staff and students of the various departments.

Table I

Organization of Engineering Doctoral Work at the University of Windsor

a. % of Department Involvement in each Division

Department	Engineering Process Design	Structures	Systems
Chemical	100%		
Civil	40%	60%	
Electrical			100%
Engineering Materials	50%	50%	
Industrial	10%		90%
Mechanical	60%	40%	

b. Departmental Research Interests

Department \ Research Interests	Structures	Electric Power	Thermofluids	Systems and Signals	Human Factors	Mechanical Metallurgy	Physical Metallurgy	Water and Air Quality	Vibration and Noise
Chemical			x					x	
Civil	x		x			x		x	x
Electrical		x		x					
Engineering Materials	x		x			x	x		
Industrial				x	x	x		x	x
Mechanical	x		x	x	x	x			x

Recommendation C11

It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977 if a favourable appraisal has not been obtained by that date.

University of Guelph

The University of Guelph has for sometime offered an interdepartmental PhD programme in Hydrology in which its Engineering School plays a part. It also plans to develop doctoral work in agricultural engineering, which it already offers at the master's level. There are no other programmes in agricultural engineering in the province.

The matter of the interdepartmental programme would appear not to be central to this assessment. It would not be inappropriate for the Civil Engineering Discipline Group to keep this programme in mind when carrying out the study called for in Recommendation C19. Nevertheless, it seems unnecessary to await the Discipline Group report to make the recommendation which follows.*

From the planning viewpoint, there seems no reason to do other than accept the University's intention to begin doctoral work in agricultural engineering, whenever it feels the time is ripe and the proposal has passed appraisal.

Recommendation C12

It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the University's plans, subject to normal appraisal procedures.

* It may be noted that COU did not accept Recommendation C19.

V. CHEMICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the chemical engineering consultants' report. There will be no reference made to Western or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C13

It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

Recommendation C14

It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

McMaster specializes in process simulation, waste-water treatment, polymer engineering, chemical reaction engineering and catalysis, and transport and separation processes, with stronger emphasis on the first two areas. The consultants feel that McMaster's goals for the future are "realistic" and appear to be "achievable and productive".

Recommendation C15

It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

The University of Ottawa specializes in three main areas including thermodynamics and transport properties; kinetics, catalysis and reactor engineering; and transport processes. There has recently been a shift towards a greater environmental emphasis. The consultants encouraged Ottawa to keep up with changes in the areas of research and graduate teaching and move into these new areas whenever possible.

Recommendation C16

It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

Queen's University specializes in the following five doctoral research areas: biochemical and environment engineering, chemical kinetics and reactor design, process control and simulation, thermodynamics, and transport phenomena. These areas cover most of chemical engineering making a rather uniform distribution of effort. The publication records of only two professors are very good, all the rest being average or low. This raises questions as to the activities of the faculty since their connections with professional and scientific societies can be described as "only mildly active". The consultants feel alarm at the number of Queen's bachelor's graduates who undertake graduate work at the same institution.

On the optimistic side, the consultants note that "the very excellent development planning and programme forecasting suggests that the department's goals and future research activities will be relevant and responsive to the prevailing needs of the province".

ACAP suggests that Queen's might consider strengthening its present faculty, or alternatively, it might consider consolidating its existing wide scope of research areas. As to inbreeding of students, ACAP draws Queen's attention to Recommendation C7.

Recommendation C17

> It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975 on action taken in regard to this Recommendation.

The University of Toronto lists eight areas of specialization, all of which show a rather uniform distribution of faculty effort. The exception is a marked emphasis on applied chemistry. The consultants would like to see an effort to group the staff in given areas of research instead of the present policy of allowing a staff member "to select his own path". The consultants did not find Toronto's statement on its plans particularly helpful and they offered no comment on it, other than to say that "it is doubtful whether any increase above the present enrolment would be beneficial to these new students or to the student body as a whole". The University of Toronto should also encourage mobility of its graduates to the benefit of other departments and of the students alike.

Recommendation C18

> It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

The University of Waterloo has grouped its research activity into five areas including biochemical and food engineering, extractive and process metallurgy, polymer science and engineering, mathematical analysis and control, and transport processes and kinetics. The scope is wide, covering a large part of chemical engineering but, there are defined groups to coordinate the programmes. Although the consultants considered the statement of goals and objectives "less positive and definitive" than others, they were pleased to note Waterloo's intention "to ensure research activities by the use of more post-doctoral fellows and hired research assistants (non-degree candidates) if this should become necessary".

VI. CIVIL ENGINEERING

The report of the civil engineering consultants contains a number of important recommendations of a general character.

Their discussion of the manpower situation supports our Recommendation C1. They suggest that it would be wise to expect rather fewer students than the totality of the stated university plans. Considering the uncertainty of the manpower analysis and the size of the numbers involved, ACAP does not feel it desirable to formulate any recommendations about individual enrolment. ACAP does advise each university to consider the likelihood that the doctoral enrolment in civil engineering may fall still further unless the fraction of Canadian students increases substantially from its present level of about 25%.

Their comments that the "study of a civil engineering speciality in depth necessitates increasingly...some graduate work", reinforces our Recommendation C2 concerning publicizing the value of graduate work.

They argue for more part-time work and closer liaison with industrial and governmental laboratories. Recommendations C2 and C8 touch on this point.

The consultants on pages A-18 and A-35 express their concern that students tend to remain for graduate study at their undergraduate universities, often being unaware of offerings elsewhere. We make recommendations on this problem in Recommendation C7.

The consultants perceive a need for "more consistent requirements of acceptance....between universities". Although we do not recommend the particular remedy they suggest we do make Recommendation C4 in this connection.

On matters specific to civil engineering, the consultants stress the need for more emphasis on fields other than structures. They call for less stress on "traditional areas, particularly structural engineering, and more stress on multidisciplinary education, environmental engineering, and transportation". They suggest that "change of programme emphasis in civil engineering (will) lead to some growth in faculty when generally universities are expecting a fairly static period". On pages A-49 and A-50, they quantify this shift by asking for a 20% reduction in doctoral enrolment in structures (i.e. a drop of about 15 students) together with a corresponding increase, roughly equally in transportation and water resources. Perhaps rather surprisingly they then suggest that no university should offer a new field at the doctoral level. (On page A-52 they also suggest that no university reduce "the range of its doctoral programmes" but on page A-51 they add "unless that university desires otherwise".)

The consequence of this stance, based on pages A-25 to A-29, is summarized in Table 2.

Table 2

CIVIL ENGINEERING

Possible Consequences of the Consultants' Recommendations on Enrolment and Field Emphasis

Universities	Fields				Order of Magnitude of Enrolment
	Geo-technical	Structures	Water Resources	Transportation	
Carleton	S	R	-	I	6
McMaster	-	S	I	-	10
Ottawa	S	R	I	-	17
Queen's	S	R	-	-	8
Toronto	S	R	I	I	25
Waterloo	S	S	I	I	30

LEGEND: R - reduce enrolment
S - static enrolment
I - increase enrolment

NOTE: Guelph, Western Ontario and Windsor are not included in the chart as they are dealt with elsewhere. (See section on University Recommendations.)

There are difficulties in accepting these recommendations. For example, if one asks what the shifts of enrolment from structures would be, to total around 15, one comes up with something like: Carleton 2, McMaster 0, Ottawa 3, Queen's 2, Toronto 4, Waterloo 4. Looking then at transportation one finds doctoral programmes at Carleton, Toronto, and Waterloo which might increase by 2 or 3 at each place. One has to ask if this is the best way to develop more high quality doctoral work. Would it be a better strategy to encourage Carleton, for example, to build a somewhat larger group than 3 or 4 students? There is another concern. Are all the transportation groups of equal promise as places to do doctoral work? If not, should some be strengthened more than others? If we really believe in penny-packet enrolments, could a fourth university perhaps enter this field? The consultants' report provides no satisfactory discussion of these questions to justify its proposals.

Equally unsatisfactory, and perhaps more basically disturbing, is the consultants' failure to give any discussion whatsoever (with three small exceptions) of the facts and reasoning which led them to conclude that all existing programmes are satisfactory. This may be so, but the rationale is far from clear. As the appended correspondence (Appendix 1 to this section) shows, the consultants decline to discharge their terms of reference, in particular C3c and the paragraph following C3d. (See Appendix D).

In particular, although the matter of critical academic enrolment size is discussed in generally acceptable terms, in that the proposition is stated that there is no a priori reason to assume a small school cannot provide as satisfactory an environment for a PhD student as a big school, the consultants neither state the characteristics of such an environment nor do they make any effort to show that it exists in the several small programmes they examined. Although it is no doubt possible to make the justification in several cases, nevertheless a question must still loom unsettled as to the academic strength (from the potential students' viewpoint) of several of the programmes, namely Carleton, Guelph, McMaster, and perhaps Ottawa and Queen's. (None has been appraised.) Of course the consultants' report, due to the lack of rationale in it, gives no reason to suppose that the larger departments are necessarily of suitable quality either.

ACAP cannot justify to itself recommending the acceptance of the consultants' plan, calling as it does for static enrolment, small shifts of emphasis in fields, and no new developments in any department. We feel that the question of the best way to develop doctoral work in transportation and water resources must be more carefully canvassed and that whatever the answer be it must be adequately justified. Some evaluation of the quality of the programme in each broad field at each university must be available before we can make any credible recommendation.

ACAP would like, at this point, to draw attention to the Discipline Group's response, Appendix B. The members of the group feel the consultants did not "seize their unique opportunity to make quality judgements" and failed to "address themselves to the question of quality in the planning function in their conclusions and recommendations." The group thinks that a statement that "documents the sundry strengths and weaknesses, if they exist, could well increase the value to those on whom the responsibility for planning ultimately rests". ACAP therefore makes the following recommendation.

Recommendation C19

> It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

We regret that this recommendation is necessary. We note (page A-5) that the Discipline Group had not prepared for the consultants the report called for by the agreed procedure (page D-6). We note also that the consultants state that they "have formed (their) own judgement about the strengths of different civil engineering departments and the areas in which they are likely to be able to attract high quality students" - we regret that the consultants are not willing to share these judgements with the Ontario university community which employed them.

NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

21 February 1974

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

Further to our recent telephone conversations, I have now heard from all my colleagues who fully agree with my letter to you of 4 December 1973.

As mentioned in this letter, we did not discuss the question of quality in our Report since none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

Moreover, we did not feel the need, nor were we required by our terms of reference, to make relative quality judgements regarding the strengths or weaknesses of individual areas or departments, because in our Report we did not recommend any change in the number or the range of doctoral programs offered by any school, including the various areas of specialization of the smaller universities.

Since the civil engineering discipline group, as well as most universities, find our Report on the whole acceptable, we think that little is gained by getting into an area which might be interpreted as an appraisal or accreditation assessment.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb
c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

4 December 1973

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

After returning from the west coast, I found your letter of 29 November and enclosures, which I read with interest.

In reply and following our terms of reference, we had not discussed the question of quality in our report since, in our opinion, none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

I am looking forward to the comments of my colleagues, in this regard.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb

c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

ADVISORY COMMITTEE ON ACADEMIC PLANNING
Ontario Council on Graduate Studies

Professor M. A. Preston
Executive Vice-Chairman

COUNCIL OF ONTARIO UNIVERSITIES
102 Bloor Street West, Toronto 181, Ontario
(416) 920-6865

Postal Code: M5S 1M8

November 29, 1973

Mr. B. V. Martin
Prof. G. G. Meyerhof
Prof. W. W. Eckenfelder, Jr.
Dr. J. L. Boulet

Gentlemen:

I am enclosing all the university comments we have received on your planning assessment report and the formal response from the Discipline Group. You will recall that it is intended to publish these statements.

You will see from the comments that there is considerable dissatisfaction in the universities and in the discipline group with your failure to come to terms with your task of giving us your findings on the relative quality of the doctoral work in the different areas of civil engineering in the different departments. We on ACAP have to agree that one of the most important aspects of the terms of reference you undertook is the statement of strengths and weaknesses of departments, and that without it the report lacks credibility. If you are asserting that all fields offered for doctoral work are competently dealt with wherever they are offered, it will follow that civil engineering is a paragon amongst disciplines. Even if true, it does not help the universities to decide which areas to strengthen.

In one of the few specific comments, you do suggest that McMaster should emphasize earthquake engineering. Do you think its work in water resources is strong enough that it should seek to expand or maintain that, or, when you recommend <u>greater</u> emphasis on water resources, do you expect this to be achieved at Ottawa, Toronto, Waterloo and Windsor for example? McMaster (and the others) would like to know. You tell the University of Western Ontario to emphasize boundary layer wind tunnel work; but what about their geotechnique? Since Guelph now has 5 students in its hydrology programme, how can it be exploiting its unique facilities for agricultural engineering if its enrolment becomes 4 to 7? Is it expected to cut back on hydrology? To consider this, it would be necessary to know how valuable Guelph's hydrology work is and how substantial is the potential of its agricultural engineering programme.

I mention these points only as examples of the kind of question on which your adivce would be helpful. The general point is that your judgements of quality by department and by area are important. You recommend that transportation be strengthened; we ask, where? If all the departments say "here", how are decisions about resource allocation to be made without the quality judgements you were expected to give?

....2/

One of the aspects of academic quality has to do with the size of the student enrolment. You will see from the university responses that there is some difference of opinion. The official position of COU, recently adopted, is as follows:

"The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design."

Recommendation 4 on page 52 of your report is not inconsistent with the above statement, but you do not indicate what criteria determine the "satisfactory environment." In ACAP we have identified two areas which we believe should be examined in this connection. One is the opportunity for the students' development through informal intellectual discussion with a peer group with common engineering or scientific interests. This peer group need not consist only of students; it may also include post-doctoral fellows. It need not be confined to one department, but may include students in other departments if there is a real sharing of research interests. The second main area for consideration has, we feel, to do with graduate courses. Assuming that a course with, say, 5 or 6 students who interact is a much more satisfactory experience than one with 1 or 2 students, we see that the desirable enrolment size is a function of course structure. If there were a programme which did not require courses, this second criterion of size would not apply. But if it is felt that students should take a substantial number of courses (as appears to be the case in all the Ontario departments), then the consideration is valid and the situation needs examination.

It appears that some of our departments plan enrolments as small as 6 to 12. It may be that some of these departments, because of specialization, course structure, post-doctoral and master's population and interdepartmental collaboration, offer an academically sound experience for the student, while other departments with the same enrolment may not. Each case needs evaluation separately.

This brings us back again to the desirability of your giving a detailed analysis of each university. We request evaluation of quality by area of study of each department, including an analysis of the kind of intellectual milieu established for a student by the enrolment size.

I hope you realize that we have a problem of reconciling the reports of the consultants on the various engineering disciplines. One report of which there seems to be pretty general approval is that dealing with electrical engineering. Of course not all its details are accepted by everyone, but the style and coverage of the report has not been attacked. I enclose a copy, since it may make clearer what I have been trying to say in this letter.

After you have had a short interval to consider the letter, I shall telephone Professor Meyerhof to discuss the mechanism of your response. We need your assistance.

Yours sincerely,

M. A. Preston/cw

M. A. Preston

MAP/cew
Enclosures.

VII. ELECTRICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the electrical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C20

It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

Other Discipline Groups might also consider this recommendation.

Recommendation C21

It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

The work in electrical engineering at Carleton is divided into two departments, Electronics and Materials Engineering which includes solid state device electronics, circuits and circuit theory, microwave electronics and electron beam systems and processes and the Systems Engineering programme which concentrates on information systems such as communications and signal processing, decision and control, digital systems design and software engineering. The coverage within these two areas is well integrated, coordinated and appropriate for PhD training. The enrolment increase proposed by Carleton is within the competence and capability of the present staff.

Recommendation C22

It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

McMaster has outstanding strength in three areas of graduate research and has plans to strengthen a fourth. These are communications and data processing, modelling and design, materials and devices and, lastly, medical electronics. The electrical engineering programme at McMaster is of high quality, with a productive and dynamic faculty.

Recommendation C23

It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

The department at Ottawa specializes in three areas, communication systems, control and systems, and computer engineering. With a faculty of 11, the consultants felt that they were spread over a rather large area of electrical engineering. A small department with a small number of staff and students can operate an effective doctoral programme only with competent professors, complementary fields of study and an adequate research environment. The consultants recommend discontinuing the programme. ACAP has considered both the consultants' report and the university's comments and has concluded that Ottawa has a contribution to make to graduate electrical engineering study in operating a specialized programme of limited scope and enrolment.

Recommendation C24

> It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

The areas of specialization at Queen's are communications, systems, electronics, and energy processing. The consultants state that the work in communications is good but is only fair in systems, and that the Department should not offer a programme in the latter two fields on a regular basis. However, we suggest that an occasional student be allowed to do a thesis in one of these fields. ACAP accepts the consultants' view about enrolment which was made on academic grounds, not for planning reasons.

Recommendation C25

> It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

Graduate work at the University of Toronto covers seven areas including communications, computers, control, power devices and systems, solid state electronics, wave sciences, and biomedical electronics. The coverage of these fields is more than adequate and Toronto's "star-studded" faculty are spread over the seven areas indicating significant breadth across the department. The consultants conclude that the Toronto department compares favourably with any of the major institutions in North America.

Recommendation C26

> It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

The University of Waterloo concentrates in five major areas including computers and communications; control, systems and networks; devices, circuits and materials; power engineering; and, antennas and electromagnetic engineering. There are two minor fields, bioengineering and electroacoustics, and these fields should be limited in size to the present level of activity. With Waterloo's highly competent faculty and well-equipped facilities, there is no question that the enrolment level planned by Waterloo can be accommodated.

VIII. MECHANICAL ENGINEERING

There are a number of general recommendations and comments made in the mechanical engineering consultants' report that are aimed at the system as a whole. Recommendations for the individual universities follow this more general section.

The mechanical engineering consultants do not anticipate any oversupply of mechanical engineers. They believe no "artificial edict" is necessary to control the number of PhDs. On the contrary, they suggest the problem will be one of availability of good students. The consultants think that Ontario might, in fact, have a shortage of mechanical engineers.

"Traditional classical" versus "applied" research projects and a shift in emphasis of study are the next problems attacked by the consultants. They feel that the doctoral education of today should shift more towards project and design activity. To this end, they advocate increased dialogue and cooperation with outside agencies such as industry and government. "If we look at the problems before us today in the fields of energy, transportation, or the environment, it is apparent that there are many gaps in the knowledge which should be attacked systematically to provide the basic design data which is essential to advances in engineering and advances generally in technology on the broad front". The consultants also recommend a change in emphasis in fields of study. Some areas of research that need to be developed are listed on page A-14.

The consultants do not condone departments that attempt to be good in all fields. They feel specialization is the key and that "considerable selectivity is required in the choice of a particular area of concentrated effort". This choice of areas of concentration should be left up to the universities. ACAP agrees with this outlook but notes that the initiatives of each department in Ontario are matters for collective consideration and advice. ACAP advises the departments to consider the consultants' suggestions noted in the addendum and asks that they report on progress made after a year of mature consideration. After this time, the Discipline Group, in its normal role, would continue to consider the development of new areas of graduate study and the possible entry into neglected fields in mechanical engineering in Ontario and would make recommendations to ACAP where change is desirable.

Another problem the mechanical engineering consultants addressed was the one of faculty age. Since the Ontario universities have been through an expansionary period in the sixties, a large proportion of the faculty is below 45 years old, consequently lacking something in maturity and industrial experience. The consultants feel that although the retirements in the next several years will be few, the universities should take these opportunities to introduce new blood by appointing faculty with industrial experience.

It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendations

Recommendation C27

It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

The Mechanical Engineering consultants, in their addendum, give valuable suggestions for focussing research activities in each department. These suggestions appear to be based on both planning grounds and grounds of academic quality, but alternative research foci may not be ruled out. Consequently, ACAP recommends that the three doctoral programmes continue but that each university note the consultants' comments and report on progress in a year's time.

Recommendation C28

It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

The consultants, in their remarks concerning the University of Ottawa, page A-17, recommend that the work in the Mechanical Engineering Department be incorporated in an interdisciplinary programme leading to an undesignated PhD degree. ACAP notes the university response, page C-14, which states that they wish to "reactivate" the doctoral programme, before discussion of this new proposal. We do not at this time make a recommendation on the future form of engineering PhD work at the University of Ottawa. There appear to be no planning reasons why there should not be a programme at Ottawa in mechanical engineering, but the consultants have serious reservations about the suitability of a number of the research projects of the department and about the limited industrial experience of its staff members.

Recommendation C29

It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

We draw the attention of the University of Toronto to the consultants' suggestion that the Department of Mechanical Engineering concentrate research on problems of major, national concern. UTIAS should note the consultants' comments on the need for selectivity within the broad spectrum of the expertise of the staff, in such areas as plasma science, low density gas dynamics, subsonic aerodynamics, flight dynamics, shockwave phenomena and noise. The consultants also favour increased interaction with work in related fields on the main campus.

Recommendation C30

> It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

ACAP notes the consultants' suggestion that the department concentrate in Production and Automation. We also take note of Waterloo's response which lists strengths in other areas. We recommend that Waterloo consider the consultants' idea of developing foci of research interest and report on any action thought desirable.

The University of Western Ontario and the University of Windsor have not been discussed here, since there is no need for any recommendations in addition to those in the section on University Recommendations, page 20.

IX. METALLURGICAL AND MATERIALS ENGINEERING

This section of the ACAP report will deal with the recommendations found in the metallurgical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C31

> It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these reommendations.

The consultants find it surprising that there is so little effort in the ceramics and glasses fields of study. Even more striking to them is the absence of any work in polymers in the Departments of Metallurgy and Materials Engineering. In their first few recommendations, they consider it very important to rectify these neglected areas and ACAP feels this is a job for the Discipline Group. They also feel it is important to strengthen already existing areas of study and in particular create at least one internationally-known centre of materials science activity.

Recommendation C32

> It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:
>
> a. recruitment of students with physics and chemistry backgrounds
>
> b. strengthening of the extractive metallurgy faculty
>
> c. collaboration with Toronto

The materials science programme at McMaster is considered by the consultants to be the best programme of this kind in Ontario and probably in Canada. It is the only programme that covers adequately the basic science related to all classes of materials including polymers. The enrolment could be easily doubled without developing the need for any significant increase in resources allocated to the programme, but enrolment, here, is limited as in so many other areas of engineering, by the number of qualified students.

The extractive metallurgy programme, although not as strong as the materials science one, provides very suitable research for the doctoral thesis. The range of the programme is, however, inadequate but cooperation with other McMaster Departments and with the University of Toronto will greatly enhance the operation of this programme.

ACAP suggests that McMaster consider the points put forward by the consultants and that the university report to ACAP on any action taken with regard to these recommendations.

Recommendation C33

> It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975 if a favourable appraisal is not obtained.

The consultants consider the programme in physical metallurgy at Queen's a good, traditional type of programme taught by young and talented faculty. Although it would make a suitable base on which to build a programme in materials engineering, the consultants do not recommend that Queen's do so.

The programme in extractive metallurgy, on the other hand, is not so well off. It is seen by the consultants to be inadequate in its present form, with too small a range of courses, too limited an amount of research activity, and ineffective interactions with other departments and programmes. But the consultants feel it is necessary to strengthen and develop this field, to provide the needed PhD graduates and maintain Queen's part in a history of leadership in Canada in mineral engineering, geology and related fields.

The enlarged programme of extractive metallurgy is envisaged by the consultants to consist of support from the Departments of Metallurgical Engineering, Chemical Engineering, Mining Engineering and Geology. ACAP realizes that cooperation cannot be legislated, but it must have some formal structure in order to make the various professors aware of their part in a cooperative venture and secure the recognition of their departments for the effort devoted to the venture.

Recommendation C34

> It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975 on any progress made in this direction.

Toronto has an international reputation for its graduate work in extractive metallurgy. However, the range of courses is limited; this situation could be improved through cooperation with McMaster. The consultants feel this would provide a good base from which to develop a programme in mineral engineering and extractive metallurgy and they advise the university to do so.

In addition to those who work in extractive metallurgy there is another group of professors in the department who describe their work as physical metallurgy and materials research. These people working with added specialists in polymers and electrical and optical properties of materials would form a group capable of mounting a substantial programme in materials engineering.

Recommendation C35

> It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Waterloo has no specific programme in materials and does not offer a PhD labelled as metallurgical engineering or any allied field. Instead, students are trained in extractive metallurgy in the Department of Chemical Engineering and there is a group of metallurgists and materials scientists in the Mechanical Engineering department. The consultants felt their effort was of such high quality that if this group were constituted as an administrative unit, they would be the strongest and most comprehensive graduate programme in materials engineering in the province. The consultants recommend setting up a separate administrative structure. However, the unit (all in one department) appears to function well without separate administration and ACAP does not feel that such a structure is imperative. Waterloo will, no doubt, consider the consultants' suggestion.

X. MINING ENGINEERING

Queen's University offers the PhD in mining engineering. This is unique in the province. Although the enrolment is small, the programme appears to fill a distinct need. The University projects no enrolment increase, showing only 4 students in 1977-78.

On the basis of the statement of future plans made by the University, we recommend:

Recommendation C36

> It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

XI. INDUSTRIAL ENGINEERING AND SYSTEMS DESIGN

This section of the ACAP report will deal with the recommendations found in the industrial engineering and systems design consultants' report. It will contain recommendations on the Universities of Toronto and Waterloo. ACAP suggests that the University of Windsor take careful note of the recommendations made in this consultants' report but at this time ACAP makes no specific recommendations on doctoral work in industrial engineering at Windsor since it is part of the earlier Recommendation C11.

The general recommendations in this report echo many of those found in the earlier consultants' reports. These consultants' estimates of manpower supply and demand closely follow those made by the other consultants and are discussed more fully in the second part of this ACAP report. Related to this is the need to increase the Canadian content in engineering programmes. Recommendations C1 and C3 refer specifically to these two points.

ACAP notes that the universities do not consider the establishment of a co-ordinating committee to be very important. We hope that talks are normally taking place between the three departments and that they will continue. ACAP feels there is no need to set up a formal Discipline Group to ensure discussions but if those concerned wish to do so it can be arranged.

Again, as in the other consultants' reports there is seen to be a need to circulate information to the student concerning the various programmes in order to ensure he selects the programme best suited to his objectives. This problem has been addressed by Recommendation C7.

ACAP endorses the consultants' recommendations 6,7,8,9 and 11 and does not wish to make any particular comments on these recommendations.

Recommendation C37

> It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

In its response to the consultants' report, the University of Toronto seems in general agreement with the recommendations made concerning its programme. ACAP notes that the Department has already made the appointment suggested in recommendation 3.

As far as future enrolment is concerned, ACAP suggests the university continue to expect approximately the same enrolment as it now enjoys. In accordance with standard appraisal procedures, a shift in fields of specialization to programmes in health systems and energy systems would require referral to the Appraisals Committee to determine whether or not an appraisal is necessary.

A review of the enrolment expectations would be made at that time. For the present, a continued output of 3 or 4 PhDs a year should be expected by the university. This should not be regarded as a quota but rather as the outcome of the present situation of fewer qualified students and falling enrolments. It should be noted that the University of Toronto has maintained a high percentage of Canadians in its industrial engineering programme in comparison to other engineering programmes both in the University of Toronto and elsewhere.

Recommendation C38

> It is recommended that the University of Waterloo continue its doctoral programme in systems design.

ACAP takes note of the response of the University of Waterloo to the consultants' various recommendations concerning the Department's isolation, its "soft" course content and the quality of recent staff appointees. Despite the possibility that enrolments may increase in this field and despite the comments from the University, ACAP considers that Waterloo should give careful attention to the consultants' recommendations for strengthening the programme before increasing the enrolment.

A P P E N D I X   A

REPORT ON DOCTORAL PROGRAMMES IN ELECTRICAL ENGINEERING IN ONTARIO UNIVERSITIES

Submitted to the

ADVISORY COMMITTEE ON ACADEMIC PLANNING
ONTARIO COUNCIL ON GRADUATE STUDIES
BY THE ELECTRICAL ENGINEERING CONSULTANTS

M.P. Bachynski, Director R&D, RCA Limited
Ste Anne de Bellevue, Canada

A.D. Moore, Professor and Head, Department of
Electrical Engineering,
University of British Columbia

M.E. Van Valkenburg, Professor, Department of
Electrical Engineering,
Princeton University

September, 1973

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September 20, 1973

Dr. M. A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Council of Ontario Universities,
102 Bloor Street,
Toronto 181, Ontario.

Dear Dr. Preston:

We have pleasure in submitting to you the Report of the Electrical Engineering Consultants on Doctoral Programs in Electrical Engineering in Ontario Universities.

Yours truly,

M P Bachynski

M. P. Bachynski,
Director R & D
RCA Limited

A D Moore

A. D. Moore,
Professor and Head
Electrical Engineering
University of British Columbia

M E Van Valkenburg

M. E. Van Valkenburg,
Professor,
Electrical Engineering
Princeton University

SUMMARY OF RECOMMENDATIONS

It is recommended:

1. That no limit or quota on production of doctorates in electrical engineering be established for the Ontario universities, but rather that the number of doctorates granted in electrical engineering be determined by (i) availability of capable graduate students, (ii) maintenance of adequate standards by the universities, and (iii) the existing capacity (staff and facilities) of the universities for giving adequate training.

2. That the heads of the departments of electrical engineering (i) jointly and on an annual basis identify those areas of research in electrical engineering which they consider relevant to the present and future needs of Canada, and (ii) put their findings into a report to be made available to the granting agencies and to various associations of industry such as the Canadian Research Management Association, the Canadian Electronics Industry Association and the Canadian Electrical Association in order to stimulate a continuing dialogue with industry.

3. That the Ontario universities (i) tighten the standards for admission to the doctoral programme in electrical engineering to accept only candidates with first-class standing and with proven research ability, (ii) establish criteria for qualification of faculty to supervise doctoral theses in those cases where such criteria do not already exist, (iii) administer more rigourously the doctoral programme in electrical engineering, and (iv) aim to decrease the average time for completion of doctoral degree requirements by one year.

4. That Carleton University, McMaster University, University of Toronto, and University of Waterloo be encouraged to carry out their five-year plans relating to graduate work in electrical engineering, including some modest increase in student enrolment where desired, subject to the constraints contained in Recommendations 1 and 3 and in the analyses of Appendix 3.

5. That (i) during the period 1974-78 the University of Ottawa stop accepting students for the doctorate in electrical engineering but increase its services in continuing education, including full and part-time degree work at the master's level, (ii) that a cooperative arrangement be worked out between the University of Ottawa and Carleton University to permit faculty from the University of Ottawa who are qualified to guide doctoral research to become visiting or adjunct members of the faculty at Carleton University, or some equivalent arrangement. (iii) that more extensive use be made of the arrangement between the University of Ottawa and Carleton University whereby graduate courses taught at either institution are accepted for credit at the other, and (iv) that the Department of Electrical Engineering be reviewed after a five-year period to determine whether improvement in administration of the programme, working relations

with local industry and government establishments, a better balance between theoretical and experimental research, and improvements in faculty and facilities had been achieved to the point where a doctoral programme should be resumed.

6. That the Department of Electrical Engineering at Queen's University (i) concentrate for the present in the fields of "communications" (including electronic instrumentation and applications of electromagnetics) and "systems", (ii) remain for the immediate future at its present level of doctoral enrolment, (iii) improve its research facilities in the above fields through a major negotiated development grant or other mechanism, and (iv) be encouraged to seek more active involvement with government and industry groups in order to overcome its geographic isolation.

7. That the University of Western Ontario (i) cease to offer the doctorate in electrical engineering but continue to offer the master's degree, (ii) carry on the research in applied electrostatics with postdoctoral fellows and research associates with the long-term goal of forming a research institute, and (iii) expand the breadth of courses available in the master's programme with the assistance of postdoctoral fellows and research associates.

8. That the doctoral programme in electrical engineering at the University of Windsor (i) continue at its present level, (ii) not expand beyond the current fields of "power" and "signals and systems" but place increasing emphasis on the latter, and (iii) be reviewed after a five-year period.

9. That the chairman and graduate coordinators of all the electrical engineering departments in the Ontario universities continue to meet at frequent intervals, meetings to be held at various institutions rather than the most central, with the aim of (i) determining areas of specialization for the different electrical engineering schools in the province, and (ii) coordinating plans for development of new programmes or areas.

10. That the heads of departments ensure that admission and support practices are not contrary to the intent of Canadian immigration policies.

CHAPTER 1

INTRODUCTION

This report is the outcome of a detailed review of doctoral programmes in electrical engineering in the Ontario universities undertaken by the present consultants as a part of the series of planning assessments being carried out by the Advisory Committee on Academic Planning (ACAP) of the Council of Ontario Universities (COU). The Ontario universities now offering doctoral studies in electrical engineering are Carleton University, McMaster University, the University of Ottawa, Queen's University, the University of Toronto, the University of Waterloo, the University of Western Ontario, and the University of Windsor.

The consultants' terms of reference, which are reproduced in full in Appendix 1, require briefly (1) that we consider all data pertinent to the doctoral programmes in those institutions, and confirm and expand upon that information by visiting the universities; (2) that we report upon the adequacy of the present state of doctoral work in electrical engineering in Ontario and in each university; and (3) that we make recommendations for the development of doctoral work in this field in Ontario for the period 1973 to 1978.

The planning assessments in engineering differ in a fundamental way from those in other academic disciplines. There is already in existence a report, Ring of Iron - A Study of Engineering Education in Ontario (December 1970), which makes specific recommendations about doctoral programmes in the province. That document, sometimes known as the Lapp Report, was commissioned by the Committee of Presidents of Universities of Ontario (CPUO) and the Committee of Ontario Deans of Engineering (CODE) with the objective of creating "a master plan which might be used as a guide for rational growth of engineering education" during the 1970's, realizing that the rapid growth of the engineering schools in the previous two decades had precluded any system planning. The report encompassed both graduate and undergraduate education in all fields of engineering and made a total of 40 recommendations, some of which contained sub-recommendations proposing specific fields of research emphasis as well as graduate enrolment limits for individual institutions. That report has been subjected to careful scrutiny, both from within the Ontario universities and from outside. COU (the successor to CPUO) received briefs on the report from CODE, from the Ontario Council on Graduate Studies (OCGS, through ACAP), and from the Association of Professional Engineers of the Province of Ontario (APEO). In October 1971, COU responded to Ring of Iron by issuing a statement addressed to the universities and to the Committee on University Affairs recommending the basis for action on the report. Only 10 of the recommendations from Ring of Iron were forwarded without amendment, and only one of those, dealing with the acceptability of "design or systems synthesis theses", was related to graduate programmes. Nine others not affecting graduate programmes were accepted with amendments. COU recommended against acting on 8 of the recommendations and 3 of the recommendations were not commented on except to note that they were redundant. Nine of the remaining 10 recommendations were divested of all reference to graduate enrolments and supplemented by an all-embracing COU recommendation:

"that for the year 1972-73 doctorate enrolment be reduced in each university below the projected figure for 1971-72 by a pro rata percentage in order to provide 612 doctoral candidates, (the number required to achieve the target of 450 in 1974-75.) Preliminary acceptance of the OCGS method for reducing PhD enrolment (by limiting new PhD enrolments to achieve a total system number of 450 by 1974-75) is based on plans for discipline planning assessments respecting PhD programmes to be initiated immediately and completed as rapidly as possible. Such assessments will be carried out by ACAP in cooperation with CODE; they are to incorporate capability, demand and quality correlates, and are to be used to provide specific recommendations on changes for the total PhD enrolment, and for the division of the enrolment amongst universities and amongst disciplines. The assessments are to incorporate a review of the effects of the pro rata reductions in 1972-73, and to recommend a mechanism for continuing review of PhD enrolments."

The remaining recommendation was amended so as to base enrolment limits on full-time equivalent students rather than the total number, apparently in response to the CODE recommendation that there be no limit imposed on part-time graduate students. In spite of all amendments, the principal thrust of Ring of Iron with reference to graduate enrolment, namely, that doctoral enrolment in engineering in the Ontario universities should be limited to 450 per year, was endorsed by COU. The essential disagreement on enrolment was in the mechanism and timing for achieving this target. The specific sub-recommendations of Ring of Iron that doctoral programmes at Guelph, Western and Windsor (of which only the latter two are of concern in this report) be terminated was not commented upon by COU, although opposed by CODE. This is consistent with the COU recommendation quoted above. But COU supported the CODE statement with reference to the recommendation for a graduate programme at Carleton and Ottawa common to the two universities, namely "CODE recognizes Ottawa's bilingual/bicultural nature and supports the continuance of Ottawa's graduate and undergraduate programmes in the traditional engineering disciplines."

It is essential, then, that the ACAP consultants in the engineering fields, though aware of the background laid by the Lapp report, must undertake their assignments with the conscious will to assess each programme de novo. This we have tried in all conscience to do.

The data at our disposal, in addition to the background information referred to above, included details for each institution for faculty curricula vitae; research support; graduate student enrolment, origins and financial support; departmental and university resources and facilities; and a statement of development plans for the quinquennium under study. The individual five-year plans of the institutions were correlated in a comprehensive statement prepared by the discipline group, included here as Appendix 2.

Subsequent to an initial meeting with the electrical engineering discipline group on April 25, 1973, the consultants visited the eight institutions in turn, spending a full day at each. At all but the University of Windsor, the three consultants were present simultaneously; at Windsor, one consultant was forced to postpone his visit, which was completed at a later date. Insofar as was possible, the same pattern was followed for all visits. The consultants as a group met with the head or chairman of the department, with the Dean of Engineering and the Dean of Graduate Studies (or their alternates), and with a representative set of a half-dozen doctoral students and in some instances, recent doctoral graduates. The consultants individually interviewed as many faculty members as possible; those interviewed were selected by the department in each case. Group or individual inspections were made of laboratory, shop, library, and computing facilities, in fact, of any facility said by the Department to be important to its doctoral programme. Questions directed toward faculty and graduate students included such considerations as procedures and standards for admission, in examination, and in administration and supervision of doctoral programmes, as well as the adequacy of funding, of space and of equipment. We are satisfied that the information now at our disposal is adequate to enable us to present a reasoned assessment of the state of doctoral education in electrical engineering in Ontario.

In this report, we present next (Chapter 2) our analysis of the economic and social factors that impinge on the really crucial question of supply and demand for electrical engineering PhDs in Canada. Chapter 3 deals briefly with some factors to be considered in the assessment of doctoral programmes in electrical engineering. Our evaluation of the doctoral programmes in electrical engineering for the Ontario university system is presented in Chapter 4. (An assessment of the individual universities appears in Appendix 3.) Finally, our recommendations for the doctoral programmes in electrical engineering in the Ontario universities for the period 1973-78 are presented in Chapter 5.

* * * * * * *

CHAPTER 2

DOCTORATES IN ELECTRICAL ENGINEERING - SUPPLY AND DEMAND

2.1 Role of Electrical Engineering

Electrical engineering, a relatively new field compared with some of the other engineering disciplines, has become over the last several decades the largest branch of the engineering profession in North America. Since World War II the influence of electronics in particular has rapidly pervaded every field of engineering and has had a marked influence on the economy and social patterns. The distribution of electrical energy, global instant communications, television, radar, the computer are only a few of the areas which have had a major impact on the world and in which electrical engineering has made a significant contribution.

An indication of the areas in a technologically advanced economy which employ electrical engineers can be obtained from an inspection of the data[1] from the U.S.A. The employment distribution of electrical engineers in 1969 in the U.S.A. is shown in Fig. 2.1 and the distribution by product or service is shown in Table 2.1. With the cutback in aerospace and defence areas the distribution is expected to shift more towards commercial areas as indicated in Table 2.2. It is important to note the wide variety of products, services and areas of technology in which electrical engineers are involved.

An important consideration is the new science-based industries which arise from innovation and which, in the U.S.A., are expanding at a larger growth rate than the traditional industries. These new industries contribute markedly to export trade and are an important source of new employment. It has been argued[2] that each PhD involved in a new innovative industry can lead to employment for 5-10 engineers, each of whom uses 10-15 skilled workers.

It is generally accepted that training in engineering has traditionally been an excellent springboard into other fields. This has been verified in a recent study[3] of graduates from the University of Toronto. Changes in the field are illustrated in Fig. 2.2. Only about 60% of the engineering graduates initially enter their chosen field of study. Others go to different fields of engineering while some go directly to non-engineering fields. This change of field is more pronounced with time from year of graduation. Much of this change is due to career

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[1] J. Alden, Proc. IEEE 9, 834 (1971)

[2] L.V. Berkner, IEEE Spectrum 1, 66 (1964)

[3] J.M. Ham, P.A. Lapp, I.W. Thompson, Careers of Engineering Graduates 1920-1970, University of Toronto, March (1973)

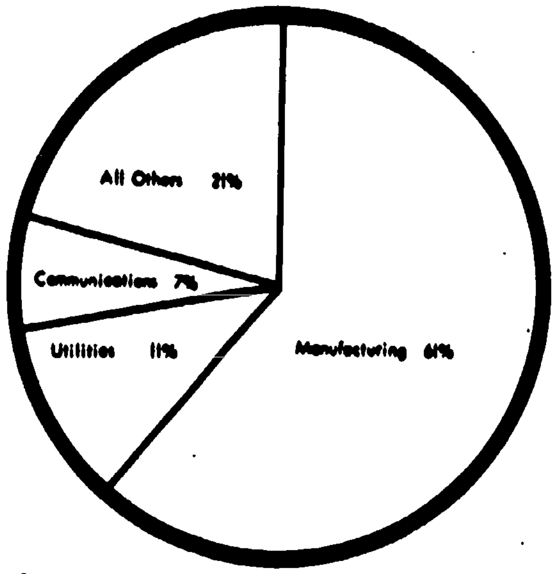

Fig. 2.1 Employment distribution of electrical engineers, 1969.

Table 2.1

EMPLOYMENT DISTRIBUTION OF ELECTRICAL ENGINEERS BY PRODUCT OR SERVICE, 1969[a]

	Percent
Electronic equipment	23
Electrical equipment	19
Utilities	11
Computers	8
Aircraft	8
Communications	7
Machinery	3
Education and information	3
All other or no report	18

[a] Source: *National Engineers Register.*

Table 2.2

ELECTRICAL ENGINEERING EMPLOYMENT DISTRIBUTION 1960 AND PROJECTED 1975[a]

Employment Area	1960 (percent)	1975 (percent)
Electrical machinery	40.74	38.21
Public utilities	9.35	5.72
Communications	6.30	5.94
Government public administration	6.10	7.24
Aircraft and engines	5.54	4.26
Business services	5.46	9.51
Professional and scientific instruments	5.37	5.23
Fabricated metal products	5.13	3.96
Machinery except electrical	3.70	4.79
Professional and related services	3.52	4.94
Educational services	1.64	3.36
Construction	1.45	1.18
Other manufacturing	2.48	1.98
All other	4.22	3.68
Total	100.00	100.00
Total employment (number)	175 000	320 000

[a] Source: U. S. Department of Labor, Bureau of Labor Statistics.

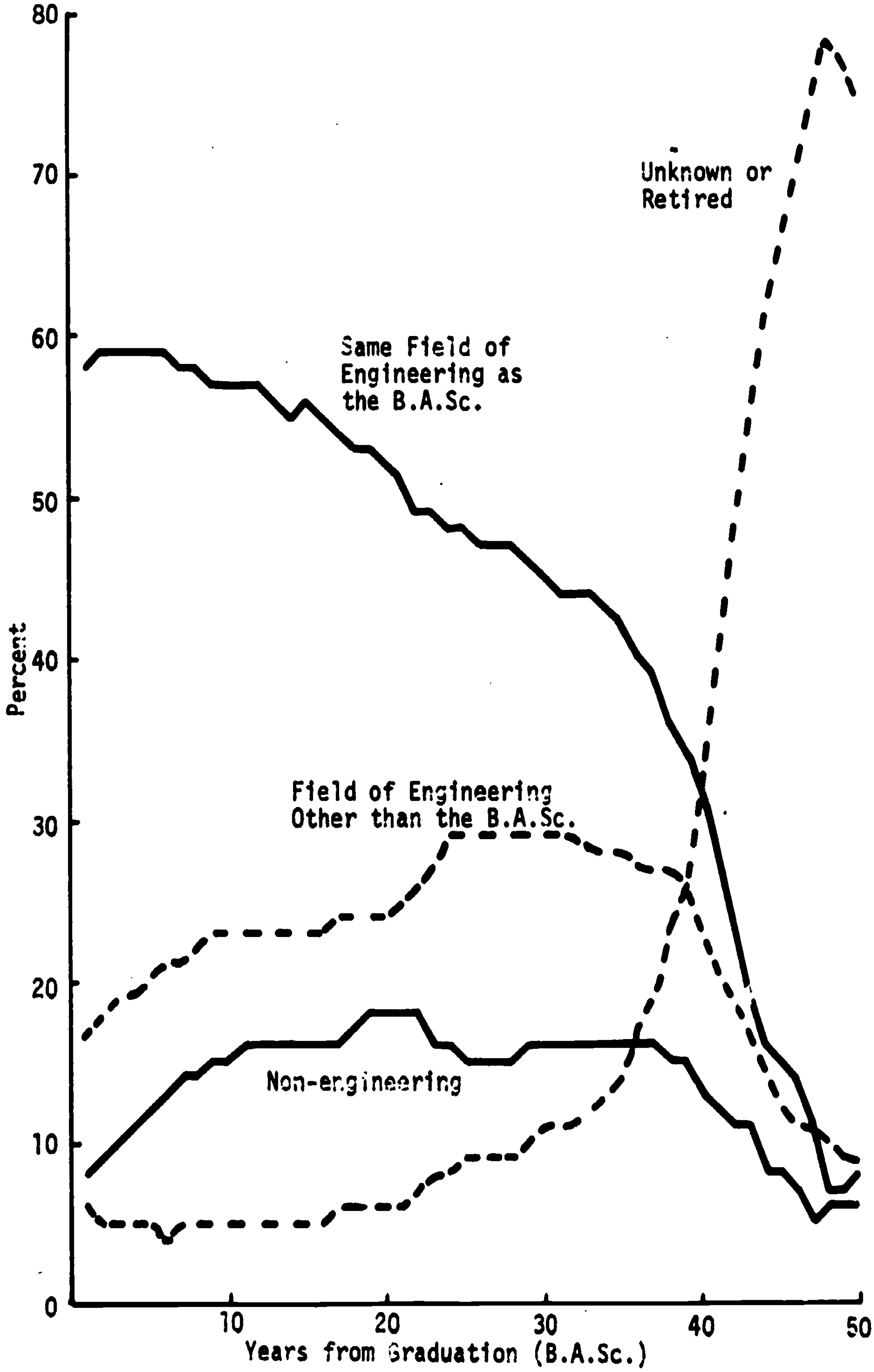

Fig. 2.2 Changes in the field of engineering by years from graduation (B.A.Sc.)

development with movement into management positions as shown in Fig. 2.3. Even the technical specialists show a major decline with time from year of graduation indicating a move into supervisory and management roles.

Much of the above data is based on bachelor's graduates in electrical engineering and on U.S. information where sufficient data is available. Since it has a key role in modern technological society, electrical engineering is obviously going to be a major factor in the national economy of Canada for many years to come. Therefore, it is considered that job opportunities in similar areas are available to doctorates in electrical engineering, together with job mobility and future positions in management.

2.2 Perspective and Trends

The rapid expansion of the Canadian post-secondary educational system during the 1960's has resulted in an increasing number of graduates at the PhD level. Initially the majority of these were absorbed into the growing educational system. However, with the saturation of job opportunities in the universities, concern has been growing regarding the imbalance of supply and demand. As early as 1969 estimates were made of an exponentially rising runaway output of PhDs graduating from Canadian universities[4] (as shown in Fig. 2.4) whereas new job opportunities were not nearly keeping pace with the supply. This has led to a cry to restrict enrolments and to close down some of the graduate schools.

Prior to initiating gross precipitous action, it is worthwhile to consider the changes that have occurred in <u>specific fields</u> during the last four years - the growth rate in doctoral graduates, the graduate student enrolment, the employment pattern for recent graduates and the employment prospects in the near future. These factors are considered for <u>doctoral graduates in electrical engineering</u> in this chapter.

In employment considerations it is important to keep in mind that the only real problem is that of <u>the first job after graduation</u>. Once a doctoral graduate has held a job it is generally much easier to move to another institution or to another job or even into another field. The first job offer is in turn extremely sensitive to the relevance of the doctoral research to the interest of the employer. It is almost a universal tenet that there will always be a demand for the graduate who has completed a doctoral project in a relevant area. Conversely, except when demand heavily exceeds supply, the graduate whose doctoral project was in a field of little interest to prospective employers will have difficulty finding that first job. Thus the university graduate schools, if they are sensitive to the needs of the country, can by appropriately

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[4] F. Kelly, Science Council Study No. 20 (1971)

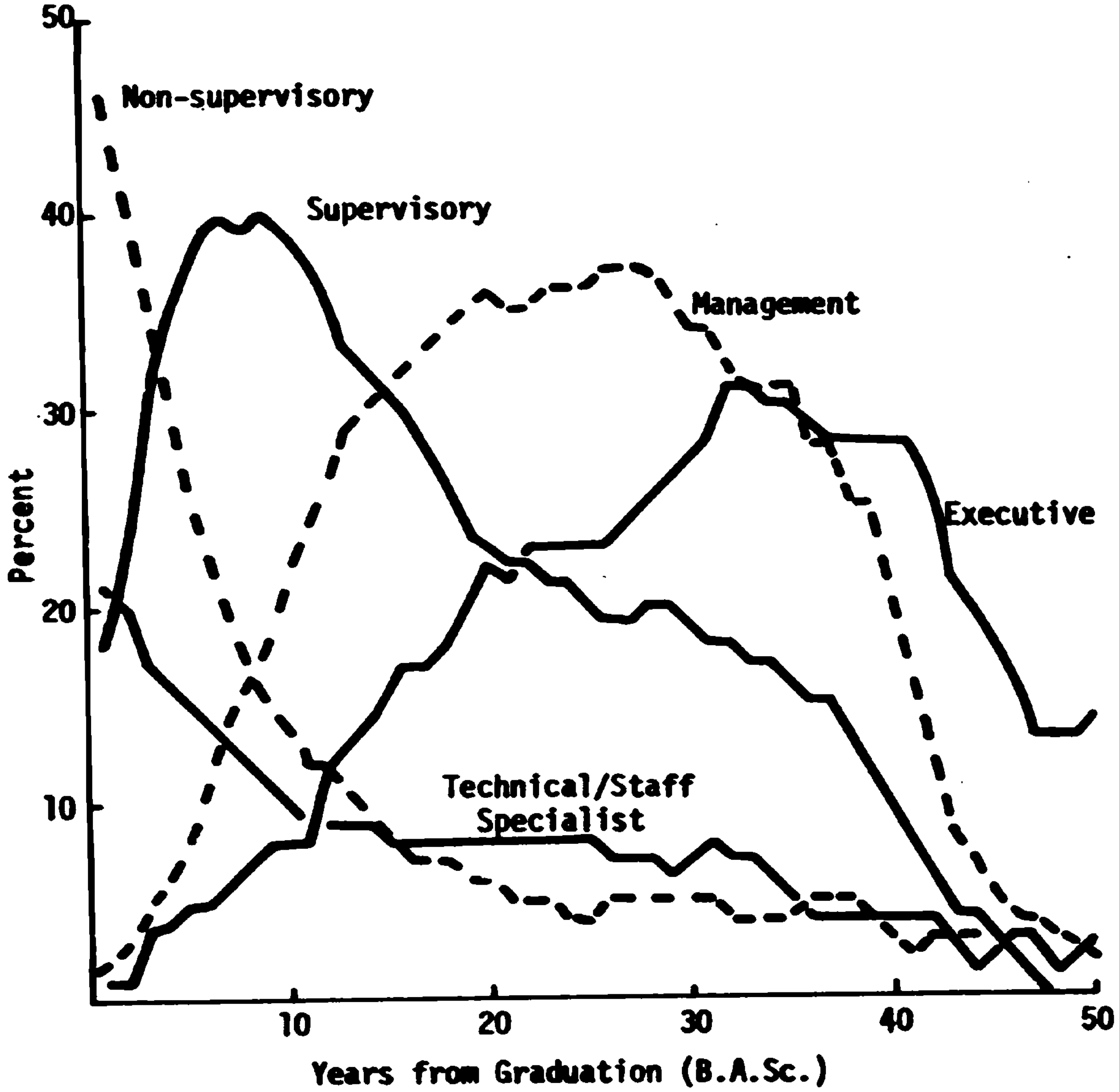
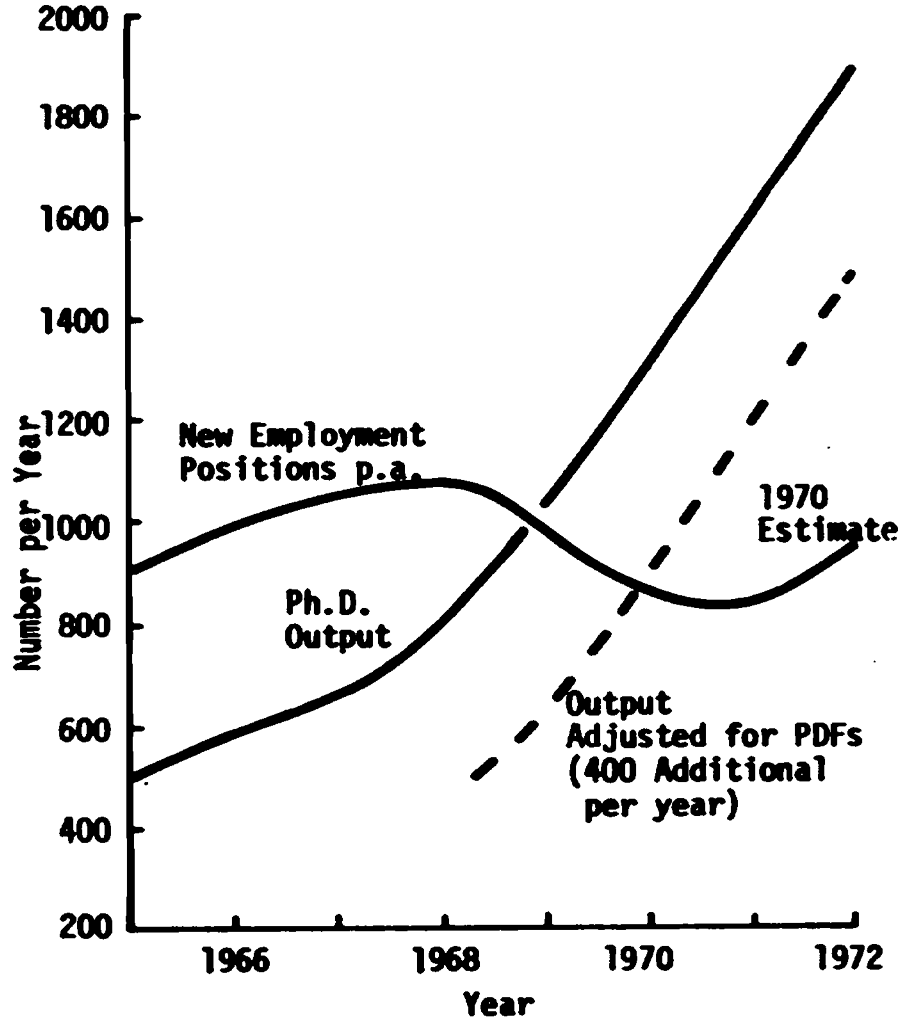


Fig. 2.3 Changes in the distribution of graduates (B.A.Sc. only) by management factor



Source: Projections of manpower resources and research funds 1968-72. National Research Council, 1969, and Science Council survey

Fig. 2.4 Early predictions of runaway production of Ph.D.'s in Canada (taken from Science Council of Canada Study No. 20) selecting their fields of research and by providing a sufficiently broad training to the graduate, exert a marked effect on the employment prospects for their graduates.

Another factor worth mentioning is that the employment situation in Canada for doctoral graduates is highly sensitive to that in the United States. A demand in the United States will lead to an emigration of Canadians to the U.S.A. while a surplus leads to Americans seeking positions in Canada. The close trade links between the two countries usually leads to a close correlation between the growth and depressed periods of the economies of both nations. Indications in the U.S.A. are that[5] "a serious shortage of engineers is developing". The prospects for electrical engineering have been described as[6] - "Very rapid growth, due to increased demand for automation equipment such as computers and numerical controls, and for electrical and electronic consumer goods."

2.3 Employment of Doctoral Graduates in Electrical Engineering to Date

Fairly complete information on the employment of their doctoral graduates in electrical engineering has been provided by the Ontario universities. The data for the last five years showing the number of graduates finding positions in each employer sector is shown in Fig. 2.5. The employer sectors include the universities, industry, government and other. The latter category encompasses the community colleges, fellowships, research posts other than fellowships and miscellaneous employers. The period covered in the data includes 1968-70 during which the Canadian economy experienced a depression and as shown in Fig. 2.6, most Canadian companies showed a decrease in the total professional staff employed in research and development. Furthermore, the university departments in engineering and in the physical sciences reached their peak size early in the period so that faculty positions were presumably saturated. Nevertheless, it is important to note that all of the doctoral graduates in electrical engineering from Ontario universities during the last five years for which information is available have been able to find employment. Positions in universities continue to be available in modest numbers, industry has increased hiring since 1970 and some government positions have been available during each of the past four years. There appears also to be a slight increase both in the non-traditional positions and in fellowships as encompassed by the "other" category. This is not meant to suggest that a number of offers are instantly available to the graduates. However, the facts suggest that with reasonable diligence, employment can be found without undue difficulty. Interviews with the students indicate that the top doctoral graduates experience little difficulty in receiving job offers, particularly if their field is one of current relevance to the country.

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5 New York Times, March 11, 1973

6 Machine Design - June 28, 1973, pp. 66-73

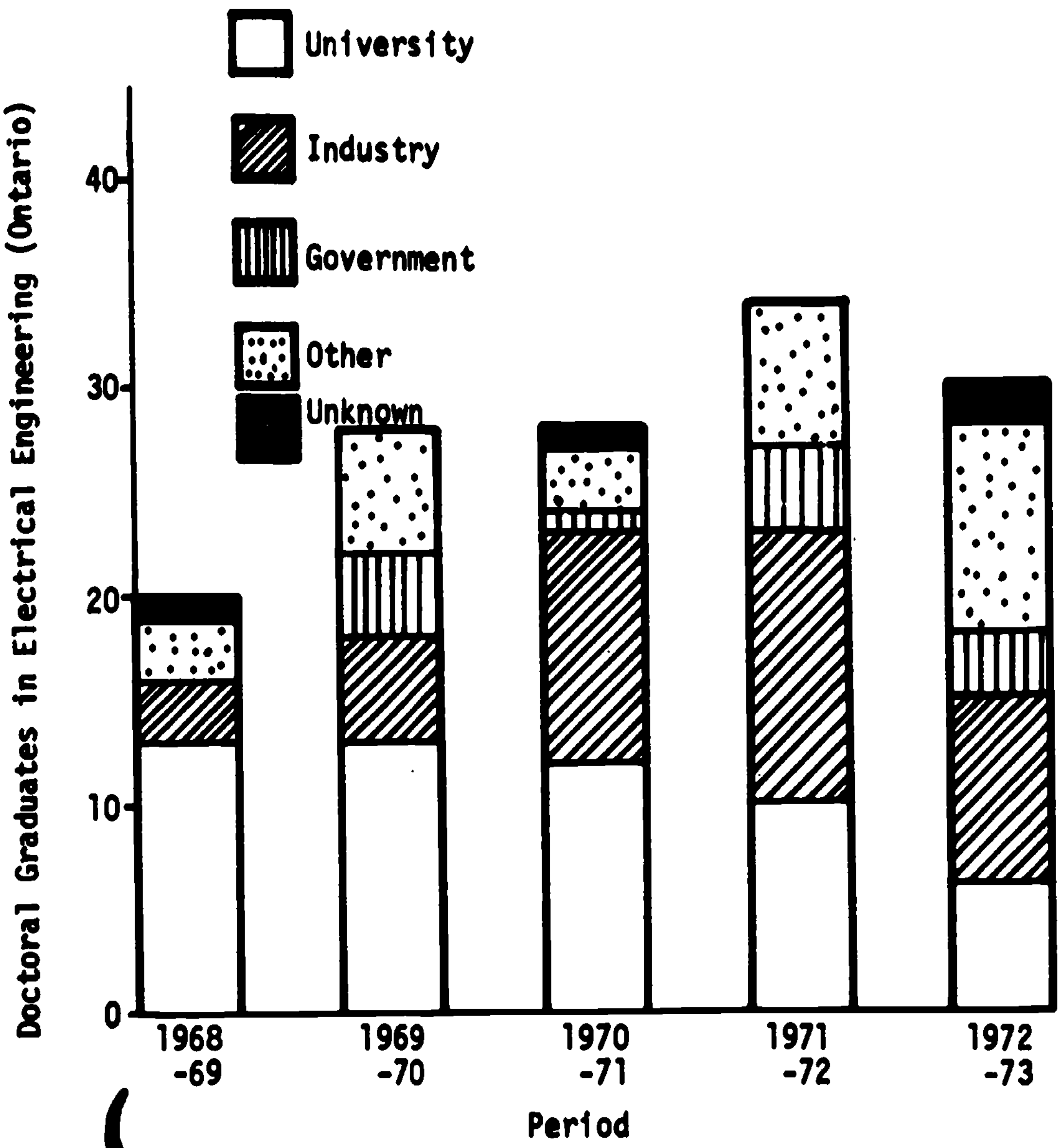

Fig. 2.5 Employment of doctorates in electrical engineering from Ontario universities by sector

S & E: scientists and engineers
Sources: DBS 13-527 and 13-532; Science Council survey

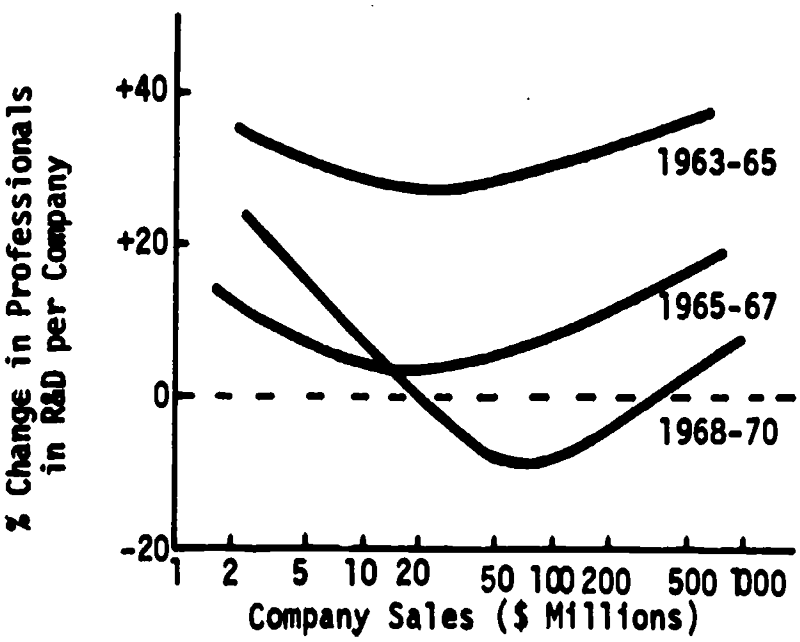

Fig. 2.6 Changes in the professional manpower of Canadian industrial R&D establishments (Science Council of Canada Report No. 20)

The geographical location of the place of employment of the doctoral graduates in electrical engineering from the Ontario universities is shown in Fig. 2.7. The number of graduates employed in foreign countries appears small during the last two years although this number was significant in earlier years (1968-69 and 1970-71). The majority of the doctoral graduates from the Ontario universities (about 70% over the five-year period and 80% during the last two years) find employment in Ontario. Overall, more than 80% of the graduates remain in Canada. The retention in Ontario of a high proportion of the doctoral graduates in electrical engineering follows the pattern established earlier for PhDs as a whole as found by the Macdonald committee[7] and shown in Fig. 2.8.

In summary, all doctoral graduates in electrical engineering from Ontario universities during the past five years have been able to find positions, the majority remaining in the province of Ontario. Thus it appears that the unemployment rate amongst doctoral graduates in electrical engineering is totally negligible and one can therefore argue that a doctorate in electrical engineering is a reasonable hedge against being unemployed.

2.4 Supply

The enrolments for the past five years in the electrical engineering doctoral programmes in the eight Ontario universities currently offering the degree are shown in Table 2.3. The enrolments are segregated into full-time and part-time students and the number who graduated from each university is also shown. The peak enrolment appears to have been reached in 1970-71 and a peak in graduates occurred in 1971-72.

Also shown in Table 2.3 are the projected enrolments* for the next five years as supplied by the eight individual universities based on their five-year plans. (The figures for 1977-78 differ somewhat from those shown in the Report of the Committee of Heads of Ontario Electrical Engineering Departments - April 25, 1973 - Appendix 2. The major difference is that the University of Waterloo lists 37 full-time candidates in the report and the total for all eight universities is 185 full-time doctoral candidates. The number of part-time candidates are not listed in the above report. For the purposes of projecting supply, only the sum of the full-time and part-time candidates as supplied by the universities will be used. It is believed that in view of current trends,

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[7] J.B. Macdonald et al, Science Council Special Study No. 7

* We consider this projection to be much more accurate than that of Thompson and Lapp (see ref. 8) who estimated the total supply of engineering doctorates and who did not make use of data available from the Ontario universities and whose projections are based on a period of development of university enrolment which has since been strongly influenced by limitations in available scholarships and by changes in immigration regulations.

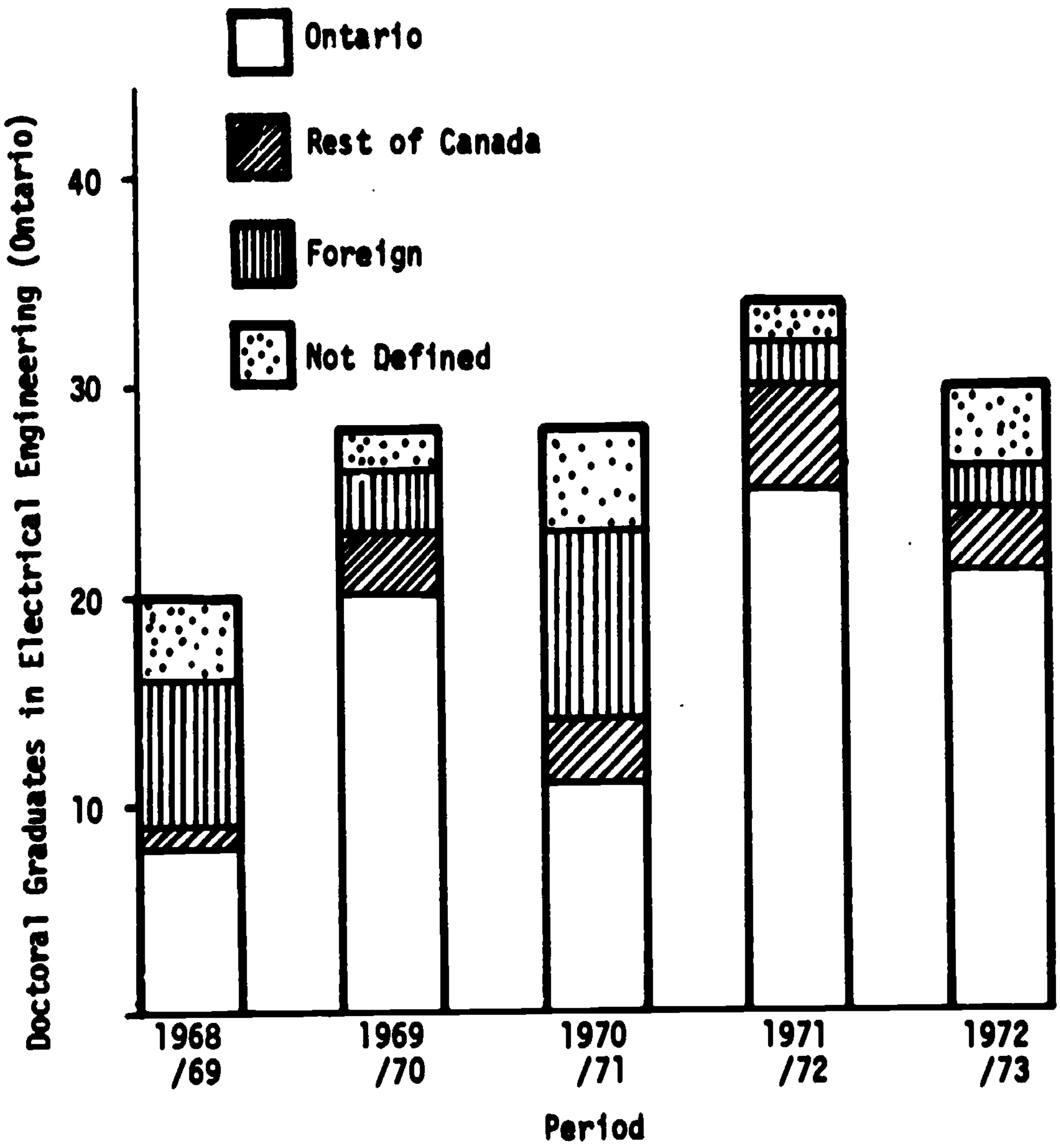

Fig. 2.7 Employment of doctorates in electrical engineering from Ontario universities by geographic location

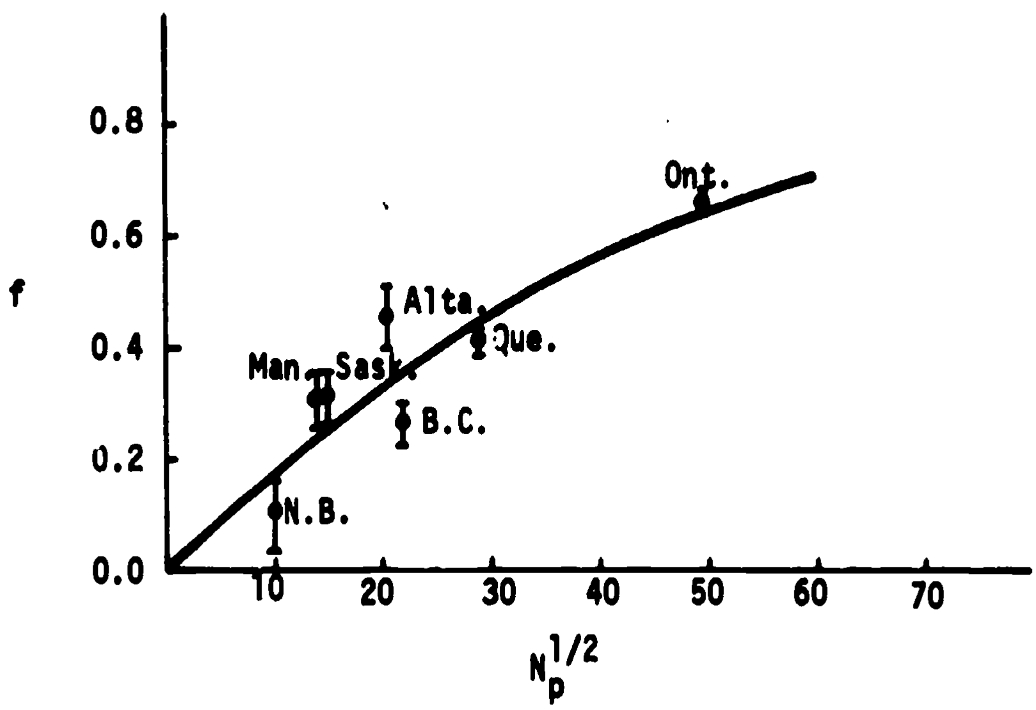

Fig. 2.8 Fraction of Ph.D.'s retained in each province vs. the square root of the no. of employment positions (from Science Council Special Study #7)

availability of suitable graduate students, and maintenance of appropriate quality standards that these represent reasonable estimates. It is also considered that had the figures in the above report been used instead, the conclusion would not be significantly different.) The use of the projections shown in Table 2.3 are not to imply support or otherwise of the distribution of candidates amongst the various universities. This topic is considered separately in Chapter 4. The projections show a very modest increase in enrolment, reaching the order of the 1971-72 level during the latter part of the five-year period (1976-77 and 1977-78).

The projected annual number of doctoral graduates in electrical engineering in Ontario has been estimated by dividing the sum of the total number of candidates (full-time and part-time) by six. This is equivalent to assuming an average period of six years for the degree. This value is somewhat less than the average for the previous five years and, if the practices of the universities remain the same, would predict a slightly larger number of graduates than would be realized.

The projections indicate that the Ontario university system will produce annually slightly over 30 doctorates in electrical engineering during the next five years, equalling their previous high of 35 attained in 1971-72 by the end of the five-year period (1977-78).

The Ontario university system thus seems to have reached virtually a steady-state situation in electrical engineering with a capacity of 30-35 doctoral graduates per year. (This is approximately the same capacity for electrical engineering, as for example, the University of Illinois at Urbana, Ill.) This saturation effect is further illustrated in Fig. 2.9 which shows the rapid growth of the doctoral programme in electrical engineering in Ontario up to about 1969-70 and a levelling-off since that time. With the Ontario system for electrical engineering doctoral work operating at a steady-state level, it is doubtful whether any major financial economies could be achieved by artificially restricting the number of doctoral candidates without simultaneous reductions in the number of faculty.

The data for all of Canada is not as recent as that for Ontario but it also seems to illustrate the same trend. From Table 2.4, which shows the total enrolment (master's and doctoral) in graduate studies in electrical engineering, one sees that the ratio of the enrolment in Ontario to that in all of Canada has tended to remain approximately constant. This includes the 1970-73 period during which any effect on graduate studies of the recommendations contained in the Ring of Iron should have begun to be felt in the Ontario system. We are therefore led to the conclusion that the trends related to graduate studies in electrical engineering followed by Ontario and by all of Canada are similar and are dictated by the variations in students applying.

TABLE 2.3 - ENROLMENT AND GRADUATES (68/69-72/73) AND PROJECTED ENROLMENT (73/74-77/78) FOR THE DOCTORATE IN ELECTRICAL ENGINEERING IN ONTARIO UNIVERSITIES*

University \ Year		68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77	77/78
Carleton	FT	10	14	16	16	12	15	16	15	17	17
	PT	11	12	17	20	20	22	22	22	22	22
	G	2	3	2	3	3					
McMaster	FT	15	15	15	18	16	18	19	20	21	22
	PT	0	0	0	0	0	0	0	0	0	0
	G	2	1	3	3	5					
Ottawa	FT	8	9	7	10	10	10	10	10	10	10
	PT	0	1	1	2	4	5	6	7	8	10
	G	1	5	1	1	3					
Queen's	FT	12	14	14	15	15	13	14	16	18	20
	PT	4	3	3	2	2	3	3	4	4	4
	G	2	2	4	4	3					
Toronto	FT	45	53	59	56	61	61	62	62	63	63
	PT	1	3	4	2	3	3	3	4	4	4
	G	6	12	6	8	7					
Waterloo	FT	49	48	44	26	24	20	20	20	20	20
	PT	5	7	7	7	5	2	2	2	2	2
	G	6	5	11	11	7					
Western	FT	2	3	3	2	2	3	3	4	4	5
	PT	0	0	0	0	0	0	0	0	0	0
	G	1	0	0	1	2					
Windsor	FT	2	5	11	9	6	8	8	8	8	8
	PT	0	0	0	0	1	3	3	3	3	3
	G	0	0	1	3	1					
Totals	FT	143	161	169	152	146	148	152	155	161	165
	PT	21	26	32	33	35	38	39	42	43	45
	G	20	28	28	34	31	31	32	33	34	35
		ACTUAL					PROJECTED				

FT = full time; PT = part time; G = graduate

* Data supplied by the universities.

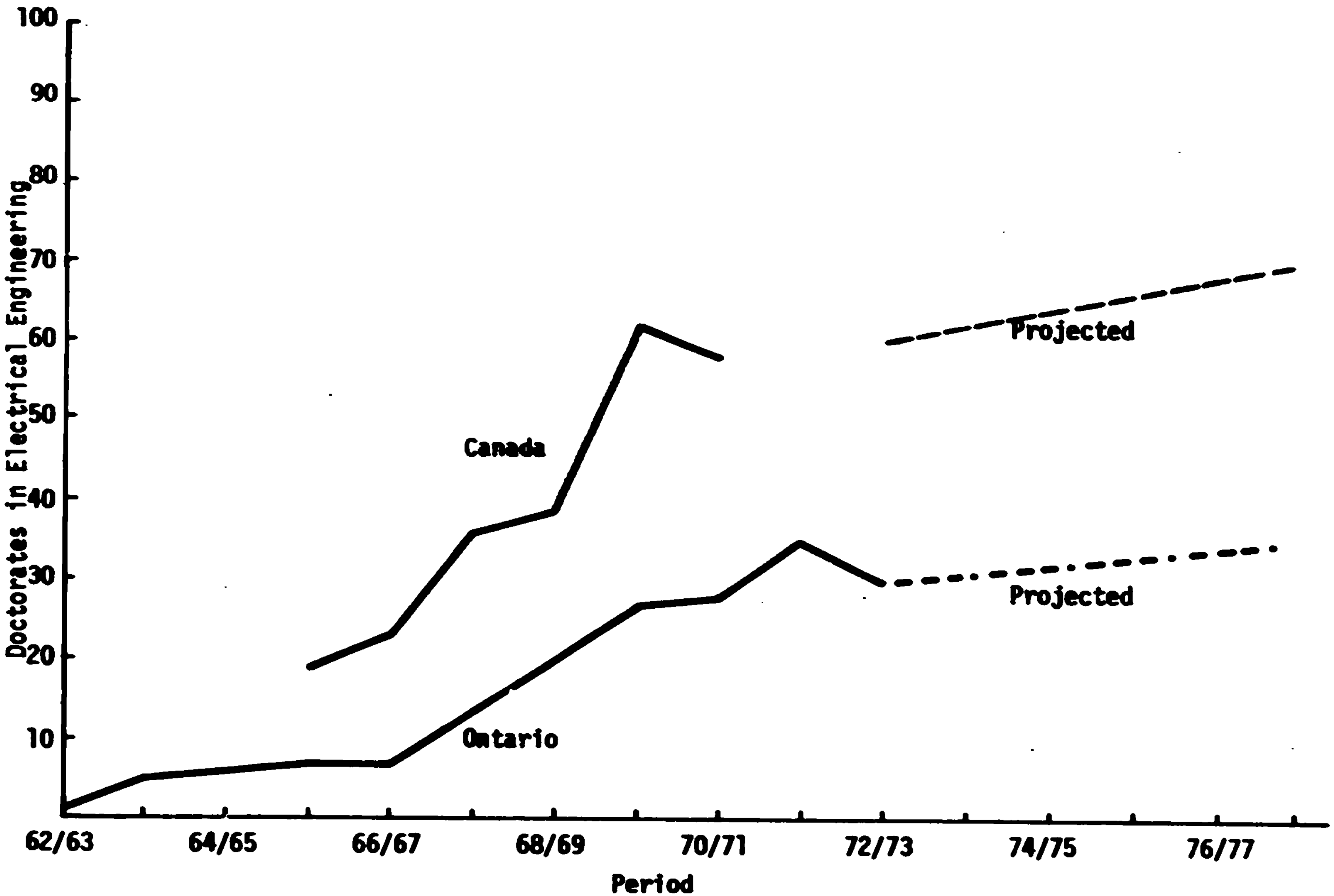

Fig. 2.9 Growth of doctorate graduates in electrical engineering in Ontario and in Canada

It is seen from Table 2.5 that the Ontario universities produce about half of the doctorates in electrical engineering in Canada. As indicated above, it is expected that this trend will continue in the immediate future and therefore doubling the output of the Ontario universities would estimate the total number of doctorates in electrical engineering produced in Canada. This trend is also shown in Fig. 2.9.

Some of the doctoral graduates will no doubt leave Canada. However, a reasonable assumption is that the emigration will equal the immigration resulting in no net gain or loss. The numbers shown in Fig. 2.9 thus represent our estimate of the supply of doctorates in electrical engineering in Canada in the next few years. It has been assumed that the enrolment of capable graduate students will increase slightly in the near future over the current numbers. This may not turn out to be the case and our estimate of supply may well tend to be high.

TABLE 2.4

GRADUATE ENROLMENT (MSc and PhD) IN ELECTRICAL ENGINEERING*

	1968-69	1969-70	1970-71	1971-72	1972-73
Ontario	413	536	541	491	503
Canada	993	1160	1231	1164	1126
Ratio: Ontario / Canada	0.416	0.462	0.439	9.422	0.447

*Source: Engineering Institute of Canada - Annual University Enrolment Information appearing in Engineering Journal

TABLE 2.5

DOCTORATES AWARDED IN ELECTRICAL ENGINEERING*

	1967-68	1968-69	1969-70	1970-71
Canada	36	39	62	58
Ontario	18	18	31	29

*Source: Thompson and Lapp[8], Tables 34 and 35

[8] I.W. Thompson, P.A. Lapp, Supply and Demand for Engineering Doctorates in Canada, July (1973)

2.5 Demand

We define the demand for manpower of a particular calibre as the number of openings for which funds are either available or can be earmarked in the future. As such, demand is closely associated with the economic climate, government policies and changes in technology. These factors are influenced by regional, national and international events. The interregional and international mobility of doctoral graduates in electrical engineering like most other highly-trained professionals is very high when the demand is high. The immigration restrictions of a particular country influence this mobility but are usually adjusted according to the demand. Thus predictions of demand are very uncertain at best and almost invariably are grossly in error. It is unfortunate that such gross estimates, uncertain as they are, often are given great quantitative significance in arriving at major policy decisions.

Very few attempts have been made to predict the future demand for electrical engineering doctorates in Canada. About the only related data is that recently assembled by Thompson and Lapp[8] for the Canadian Engineering Manpower Council. Their survey relevant to demand for doctorates in electrical engineering is summarized in Table 2.6.

TABLE 2.6

DEMAND SURVEYED FOR DOCTORATE GRADUATES IN ELECTRICAL ENGINEERING IN CANADA (THOMPSON AND LAPP)

Sector	Demand in	1974	1975	1978
Federal Government		3	3	3
Provincial Government		-	-	-
Provincial Research Institute		-	-	-
Industry (with demand)		25	31	38
Industry (without demand)		-	-	-
Industry (future demand)		2	1	3
Education		-	-	-
		30	35	44

There are obvious shortcomings in the above survey. The predictions that the Federal Government will require electrical engineering doctorates at a rate of 3 per year seems incredibly low in view of the activities of the Federal Departments. Similarly, the demand in education is considered negligible whereas the actual employment of Ontario doctoral graduates in electrical engineering shows from 6-14 being absorbed annually by the universities in recent years (see Section 2.3). The survey did not include the largest employers of electrical engineers in Canada, namely Bell Canada and Northern Electric Company. It is difficult to understand why only the Bell Northern Research Laboratories would be the sole employers of doctorates in the Bell-Northern system. It is not clear whether the potential employers surveyed considered the possibility of positions being made available through promotions of the doctorate personnel they currently employ. The growth in organizations in Canada associated with computer science, computer communications, numerical controls and electrical and electronic comsumer goods which normally would employ a large number of electrical engineers is expected to be significant in the next five years. However, the survey does not reflect these organizations as employing electrical engineers at the doctoral level.

Thompson and Lapp recognize the limitations of their survey and as a result have adjusted the predictions for demand including a high limit and a low limit. The Thompson-Lapp survey of potential employers indicates that of the total demand for engineers at the doctoral level, 24% in 1974, 23.2% in 1975 and 25.9% in 1978 was explicitly for electrical engineers. We can therefore reasonably assume (well within the accuracy of such predictions) that 25% of the demand for engineering doctorates is in the field of electrical engineering. Thus normalizing the Thompson-Lapp demand predictions for all engineering doctorates by the factor 0.25 should give their predictions of the demand for doctorates in electrical engineering.

The Thompson-Lapp survey also reveals a demand for engineering science graduates of 17 in 1974, 17 in 1975 and 15 in 1978. The majority of these demands were in the electrical/electronics industries. Since few universities in Canada are known to offer such degrees,* these positions would presumably be filled by graduates from either physics <u>or</u> electrical engineering. Assuming that the demand for engineering science graduates could be filled by electrical engineers then the Thompson-Lapp survey indicates that 38% of the total demand for engineering doctorates in 1974, 34% in 1975 and 35% in 1978 could be satisfied by doctorates in electrical engineering. Therefore, one can argue that applying a normalization factor of about 0.33 to the Thompson-Lapp demand estimates for all engineers would indicate the demand for doctorates in electrical engineering.

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* It should be noted that a large portion of engineering science baccalaureate take their doctorates in electrical engineering.

We compare the demand as estimated by each of the above assumptions with the projections of supply as determined in Section 2.4. The comparison using the factor of 0.25 is shown in Fig. 2.10. The results show that the Ontario production is well below the "demand adjusted low" while the total Canadian production falls between the medium and high adjusted demand. It suggests an overproduction in Canada in 1974. The demand estimates normalized by 0.33 are shown in Fig. 2.11 together with the supply projections for Ontario universities and for Canada. These estimates indicate that except for 1974, the demand for doctorates in electrical engineering is likely to exceed the supply.

Extrapolating the demand backwards in time to 1973 would suggest a rapid decline in demand in 1974 compared to 1973. Otherwise a serious unemployment crisis would exist for 1973 graduates. Since we know of no unemployed 1973 graduates, nor conditions which would make the demand in 1974 significantly less than in 1973 we are led to the conclusion that the 1974 demand estimates are likely low. It is also noteworthy that the slope of the variation of supply with time is less than the slope of the variation of the demand except for the most pessimistic projections.

Based on the assumptions inherent in the comparisons shown in Fig. 2.10 and Fig. 2.11 we arrive at the conclusion that within the accuracy of such projections, the demand and supply of electrical engineers at the doctoral level in the next five-year period will be approximately in balance.

2.6 Supply and Demand of PhDs in Electrical Engineering in the U.S.A.

Because of the close relationship between supply and demand of highly-qualified manpower in Canada and the United States, an examination of recent trends in the U.S.A. might be useful. Studies of the number of PhD degrees awarded in electrical engineering in the U.S. agree that there was a linear increase during the decade of the 60's. Recent studies have sometimes extended this increase through the 70's in making predictions of supply. Such a linear extension is not justified by the actual data which is available. Beginning in 1970, the enrolment began to decline. In electrical engineering, the rate of decline has been about 8% per year. The number of degrees actually granted reached a peak in 1970, and has also been declining since that time. Since these graduates represent students in the "pipeline" at the time of the change which occurred in 1970, the decline represents students who have changed their plans as a result of the widely announced oversupply of PhD holders. It can be expected that the number of PhD degrees in electrical engineering actually awarded will decline even more once the results of the smaller size of the entering class, which is the factor contributing to the declining enrolment, have been felt.

Another factor relating to supply of PhDs is the change in U.S.A immigration laws. Until the early 70's, most foreign students who studied in the U.S. expected to remain in the U.S. and most of them

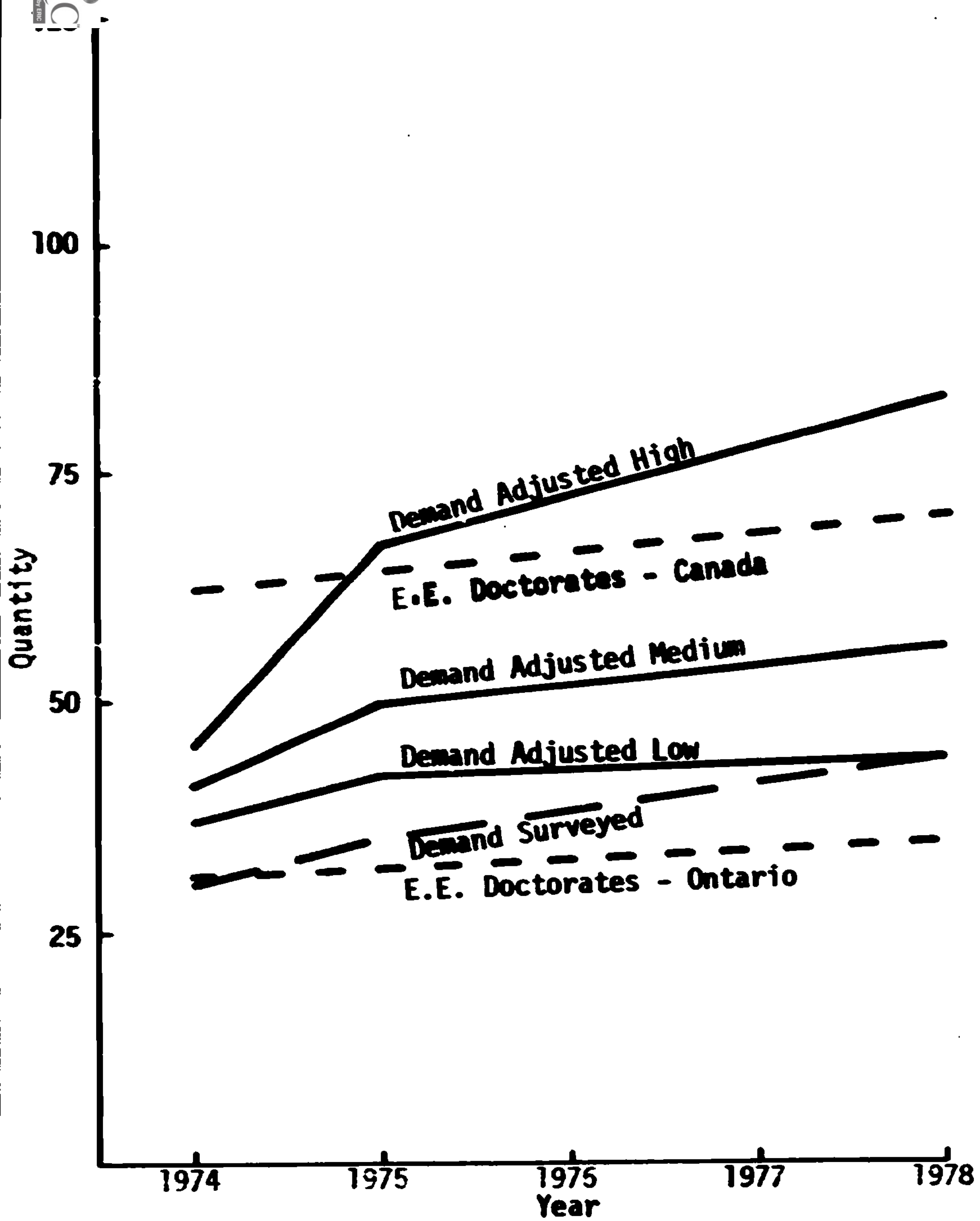

Fig. 2.10 Demand for doctorates in electrical engineering (based on Thompson-Lapp estimates and assuming 0.25 of total demand for engineering doctorates is for electrical engineers)

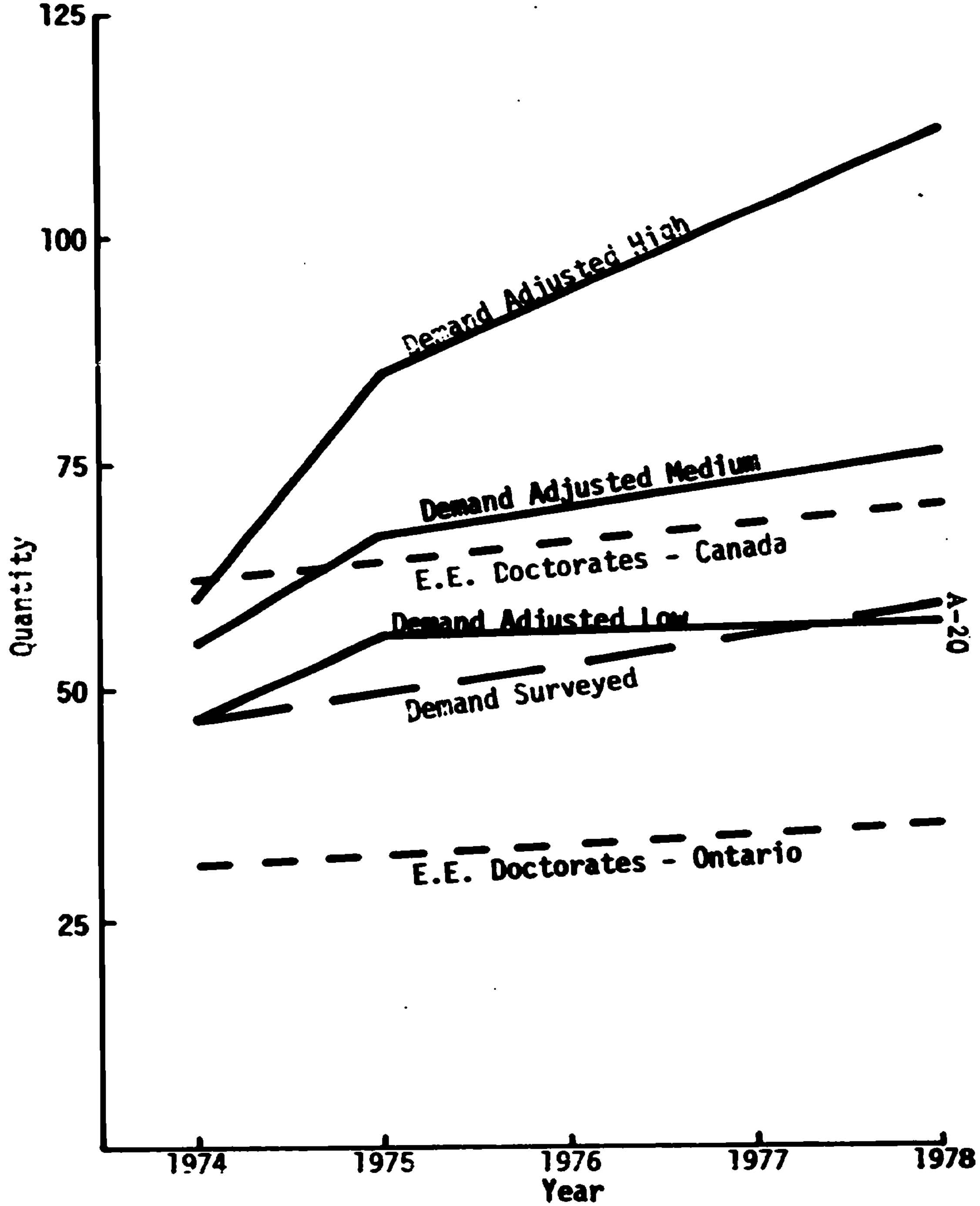

Fig. 2.11 Demand for doctorates in electrical engineering (based on Thompson-Lapp estimates and assuming 0.33 of total demand for engineering doctorates is for electrical engineers)

actually did. It is now almost impossible to change a student visa to permit even temporary residence in the U.S. In addition, U.S. industry has been reluctant to accept non-U.S. PhD holders for employment for a variety of reasons, one of the most important being the short time of expected stay in the U.S. Estimates of the number of non-U.S. students in graduate schools vary, but the lower limit is no less than 25%, and the upper limit may be 50%. A good guess might be 35%, making the number of PhD holders actually available for employment in the U.S. only 0.65 times the number receiving degrees.

Estimates for the demand are more difficult to make. It is observed, however, that all studies made in the past anticipate that the demand will increase with time. This statement includes the analysis by Thompson and Lapp[8] and the estimates made by Fleckenstein.[9] These predictions seem to be in agreement with present-day observation. After the gloom of the early 70's, the oversupply of engineers has changed to a shortage of engineers, and this appears to be true at all levels. The number of unemployed engineers in the U.S. is now estimated to be less than 1%. If it is that high, then the source of this unemployment is surely the mid-career engineers who lost technical competence. The common experience at the universities is that all engineers find employment if they are citizens of the U.S.

If we accept the fact that the demand approximately equals the supply at present, that demand is increasing, and that supply is rapidly decreasing (and will continue to do so because fewer are entering the "pipeline" which will produce the PhD graduates in the next five years or so), then we conclude that the shortage of engineers at the PhD level will become even more apparent with the passing of time, at least for the next five years.

Information on supply of PhD enrolments and degrees granted is readily available from ASEE reports.[10] In these reports, each university supplies figures on enrolments and degrees awarded for each degree-granting department. Figure 2.12 shows the increase in PhD degrees in engineering until the levelling-off of the 1970's. Over the last four years, the ratio of electrical engineering degrees to all engineering degrees has ranged from 0.29 to 0.31, or an average of 0.30. Hence, approximately 0.30 of the number shown in Figure 2.12 represents electrical engineering graduates. To get a detailed picture of trends in electrical engineering, 25 prominent departments which together grant most of the PhD degrees in the U.S. were selected. Variations in enrolment for several of these are given in Table 2.7. The overall change in enrolments and degrees granted is shown in Figure 2.13.

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9 William O. Fleckenstein, IEEE SPECTRUM, 8, pp. 63-71 (December, 1971)

10 ASEE "Engineering College Research and Graduate Study" Section of the Annual Directory of ASEE. ASEE, Washington, D.C., U.S.A.

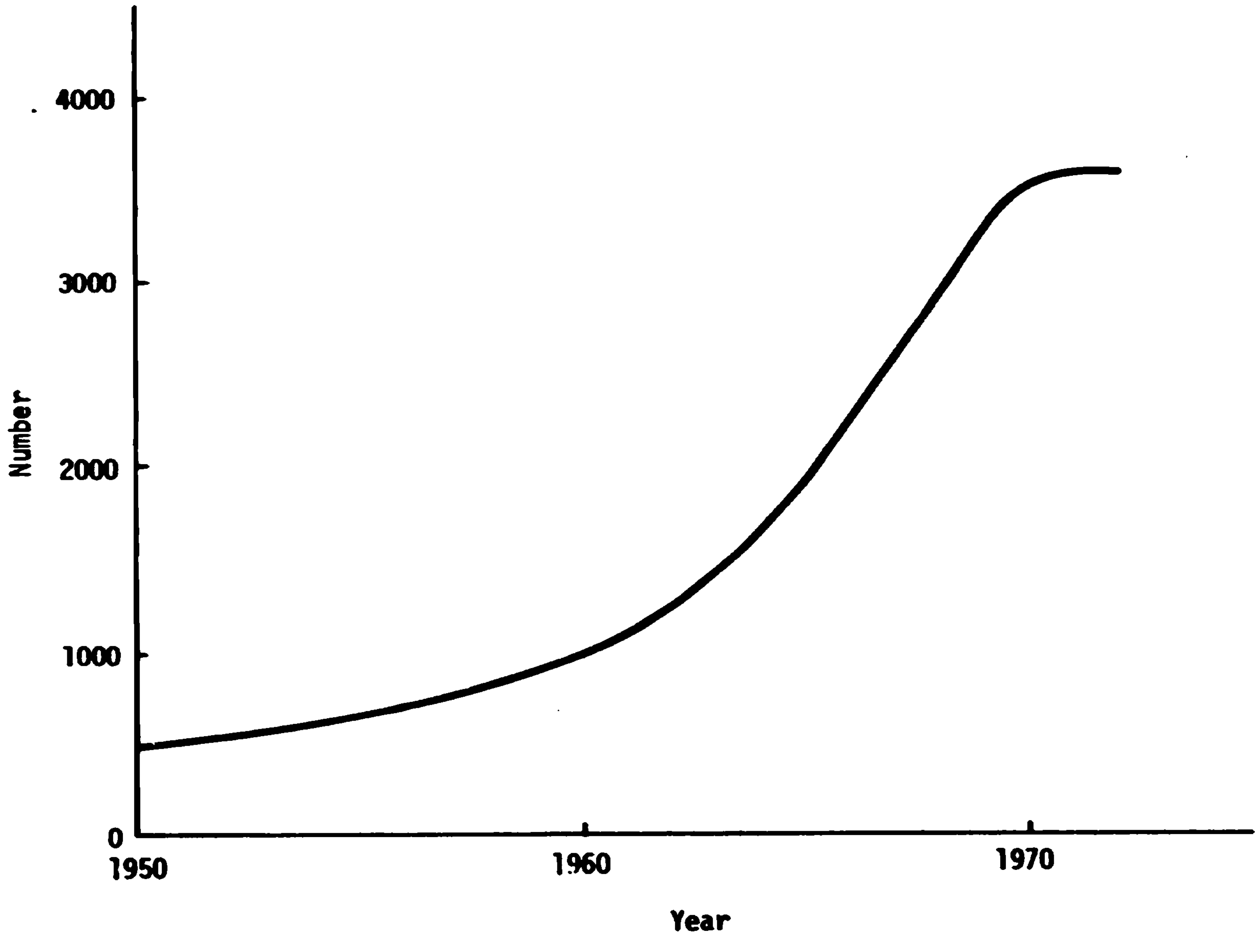


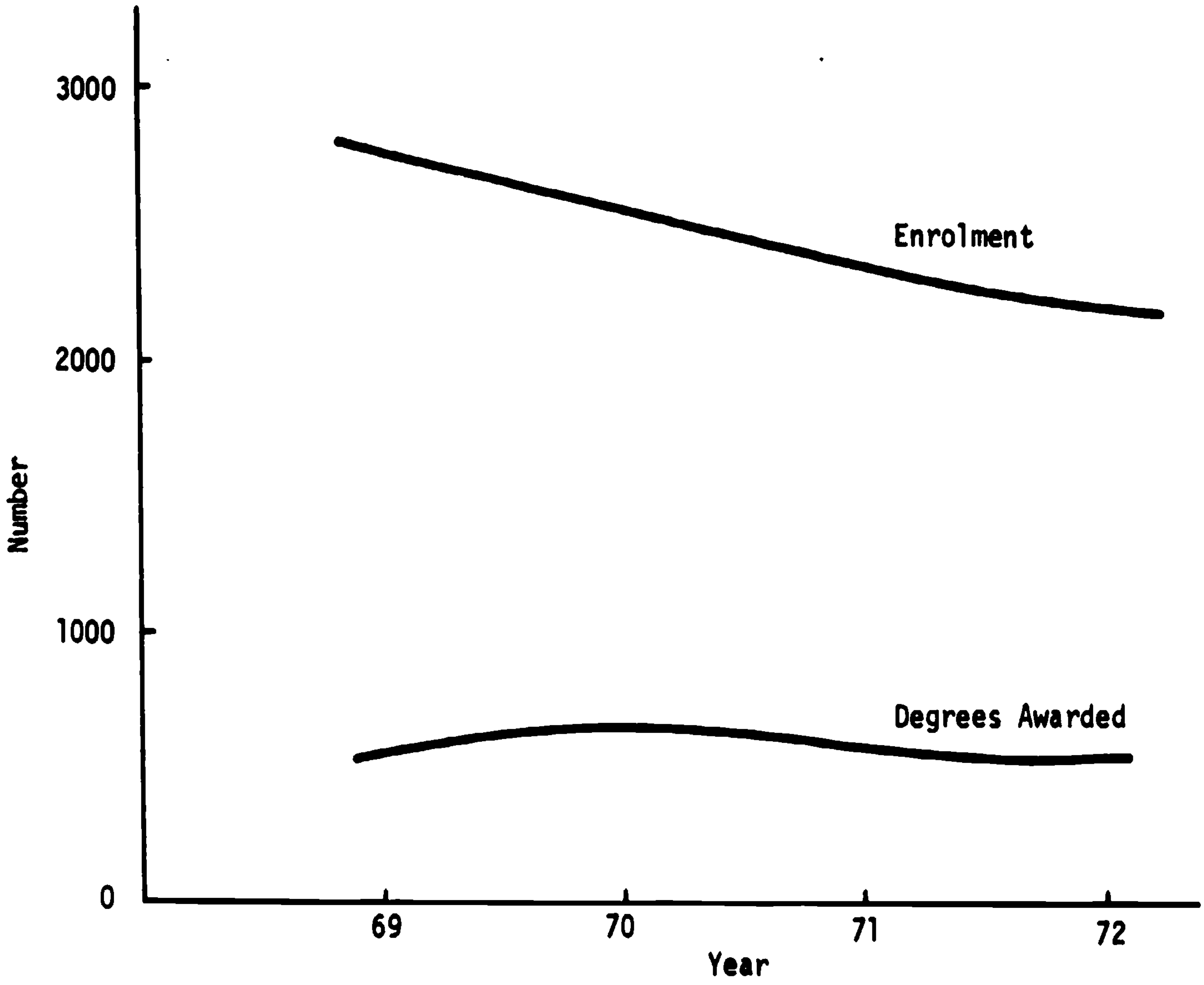
Fig. 2.12 Doctorates granted in engineering in the U.S.A.

TABLE 2.7 - ENROLMENT TRENDS IN ELECTRICAL ENGINEERING AT U.S. UNIVERSITIES

	Ph.D. Students Enrolled, Fall of:			
	1969	1970	1971	1972
I. DECLINING ENROLMENTS				
Carnegie-Mellon	96	85	72	61
Cornell	77	68	45	40
Georgia Tech	51	48	32	34
MIT*	437	514	456	443
Michigan State	59	79	35	29
Minnesota	70	63	47	41
Northwestern	46	40	30	26
Pennsylvania	351	308	280	251
U.S.C.	185	173	130	118
II. STEADY ENROLMENTS				
California, Berkeley	208	212	208	209
Illinois, Urbana	132	154	131	137
Ohio State	122	122	132	131
Princeton	54	47	58	59
III. INCREASING ENROLMENTS				
Stanford	283	239	262	331

*For MIT, the figure given is all advanced students (M.S. + Ph.D.)

Source: ASEE Directory of Engineering College Research and Graduate Study for each of 1970, 1971, 1972, 1973.



Source: ASEE Engineering College Research and Graduate Study for 70, 71, 72, and 73. ASEE, Washington, D.C.

Fig. 2.13 Trends in doctoral enrolment & degrees awarded in E.E. in 25 major U.S. universities

A careful study of demand for electrical engineers was made by Fleckenstein[9] in 1971. The results are shown in Figure 2.14. Fleckenstein made use of extensive sources including trends in the Federal budget, GNP growth and like factors in arriving at the estimates of an ever-increasing demand. It is probably the best source of information presently available, and similar in the rate of increase to the recent conservative estimates made by Thompson and Lapp.[8]

The manner in which the supply and demand curves might mesh is suggested by Figure 2.15. For a long period of time, the demand exceeded the supply - the time prior to time A shown in the figure. For a brief time, the supply exceeded the demand, with the shaded area being proportional to the total number not gainfully employed. At time B, the supply and demand curves crossed. At time C, the shaded areas from A to B and from B to C just matched, so that all PhD degree holders were employed. Granting that the demand curve will increase while the supply curve must decrease with absolute certainty (since they will come from the "pipeline" source now existing for the next four to five years), then there must be a shortage of PhD degree holders until one or both of the trends is reversed.

It should be observed that the analysis just given agrees with the personal observations of many U.S. educators. The U.S. PhD trained in a viable field has no dearth of employment opportunities. These opportunities are, for the most part, in industry or government. Yet there are several specialties for which there exist openings in junior ranks of the faculties of U.S. universities.

2.7 Need

We define "need" in highly-qualified manpower as the number of trained people necessary to achieve specific goals or way of life in a country. These goals are markedly influenced by the economy and sense of priorities of the nation.

In Canada, the areas of future importance appear to include energy, communications, the environment, computer applications, new secondary manufacturing industries, health care delivery systems, etc. All of these will involve a significant component of sophisticated electrical engineering in order to implement any major programmes. Similarly, the achievement of the national goals proposed in the Science Council's Report No. 4 would require significant contributions from electrical engineering and major increases in the number of highly-qualified manpower in this specialization. The employment of natural scientists and engineers in Canada as a percentage of the total labour force as shown in Figure 2.16 lags significantly behind that of the United States. This factor may contribute appreciably to the lag in manufacturing industry and industrial productivity in Canada and could become more serious with the rapidly expanding Canadian labour force.

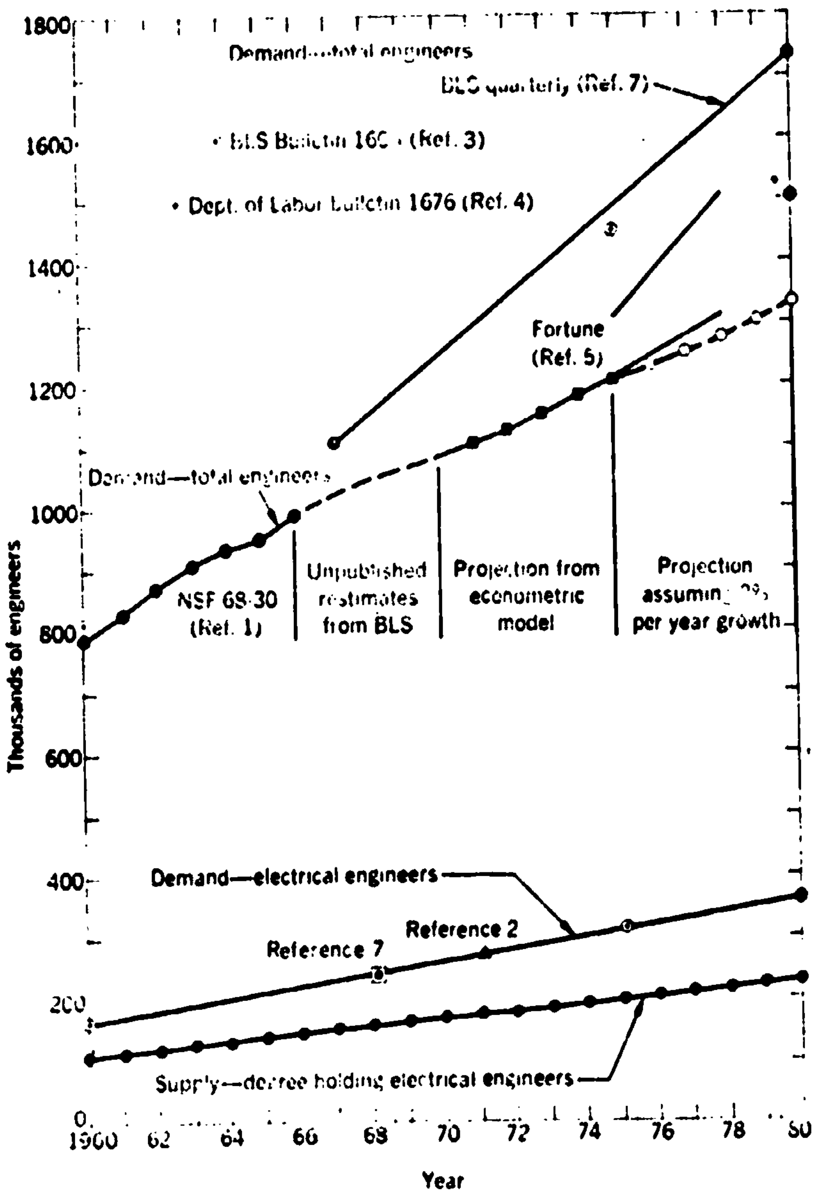


Fig. 2.14 Engineering employment, showing sources of data (from Fleckenstein[9])

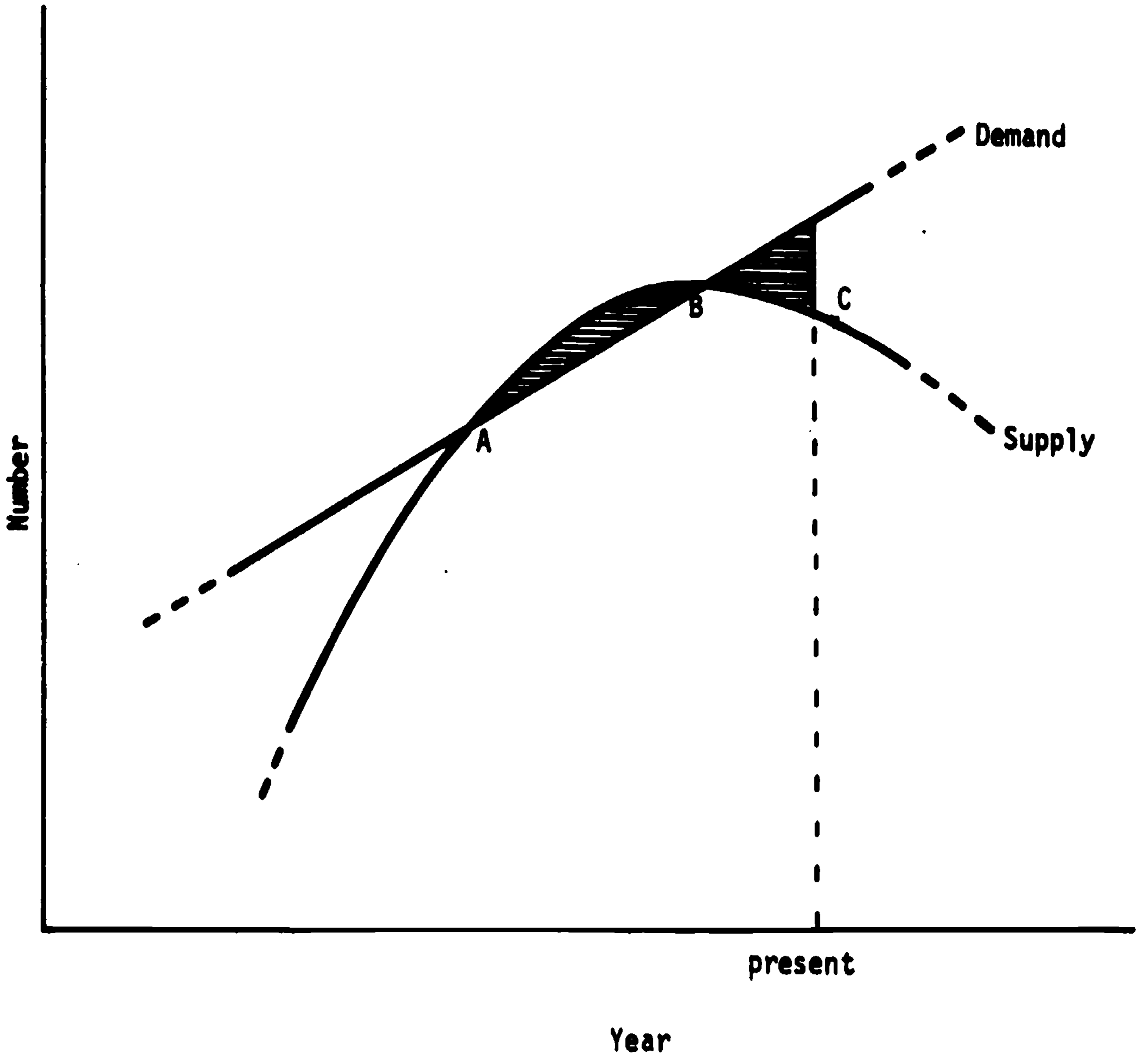


Fig. 2.15 Suggested variation of supply and demand for electrical engineering doctorates in the U.S.A.

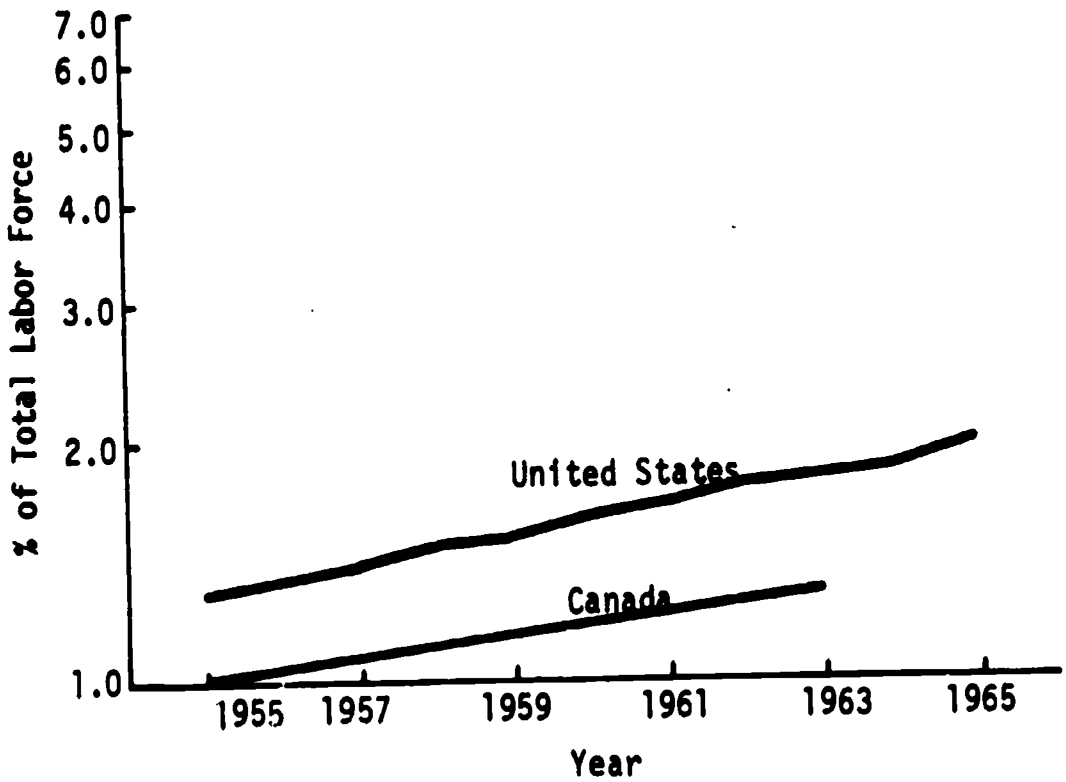


Fig. 2.16 Employment of natural scientists and engineers as a percentage of the total labor force (Science Council Special Study No. 6)

Thus it appears that there is a major role for highly-trained manpower in electrical engineering in the achievement of future Canadian goals and ambitions. Consequently, any underproduction of graduates in this field could have significant social consequences in Canada, not being in a position to achieve these goals. An overproduction of graduates would have less serious consequences in that it would force certain positions and competence to be upgraded and might force entrepreneurial activities which may be beneficial to the country.

There is a developing tradition for PhD graduates to start their own companies, especially in areas of high technology. If this happens more frequently within Canada, there will be a consequent multiplication of the number of jobs available.

Past experience shows that diffusion into other areas is easily accomplished with a background in electrical engineering.

2.8 Specialization and Future Manpower Needs

It seems clear that future doctoral graduates will find employment in industry and government, few will find employment in university teaching (at least in North America) and that applications will be stressed at the expense of basic research (with abstract studies vanishing). This is a dramatic shift from the situation which has prevailed for the past two decades. Because of the close relationship of the field of specialization to first job, some fields will require priority over others.

The PhD should find employment in high-technology industries to a much greater extent than in mature manufacturing or processing industries. To determine the fields within electrical engineering that should be stressed, one has to determine the high technology industries that are likely to thrive in Canada in the next five to ten years. It should be possible to identify some of these. Some guesses are the following:

Tasks for the PhD in Electrical Engineering	Percentage of Effort
Digitalization of things - gadgets, operations, processes, tasks, etc.	30%
Expansion of facilities for telecommunications and data communications	25%
Automation of industry and services	20%
New energy sources and means for distribution	10%
The provision of health maintenance facilities and health delivery care (bioengineering)	10%
Solve the urban problems - a systems approach to new cities, new transportation schemes, new and efficient services	5%

Of course these are not thesis subjects directly, but they can relate to such a list. In general, the faculty member must move to areas that will allow the new graduate to accept a position directly in a high-technology industry. A list of new research areas, in contrast to the old, might be as follows:

FIELDS

Highly Mature	Emerging
Shannon-type Information Theory	Many-user Communications
Analog-modulation Techniques	Digital Communication Systems, Computer Nets, O.R. Aspects
Sampled-data Systems	Large-scale Systems (Linear & Non-)
Linear Systems	Robotics, Pattern Recognition, Speech Recognition
Switching Theory	Graceful Degradation
Wiener Filters	Large-scale Integrated Circuits
Alphanumeric Recognition	Integrated Circuit Modeling
Bayesian Statistics	L.S.I. & I.C. Electronic Systems
Classical Circuit Theory	Optical Propagation (Linear & Non-)
Sensitivity Analysis	Propagation in Random Media
Discrete Component Electronics	Fiber Optics, Optical Signal Processing
Boundary Value Problems	Charge-coupled Devices
Antenna Theory	High-temperature Devices
Geometrical Optics	Ultrasonic Cameras, Artificial Organs
Minority Carrier Devices	
Cryogenic Computers	
EKG Signal Analysis	

2.9 Conclusions

No exponentially increasing production of doctoral degrees in electrical engineering is to be found in the Ontario university system. Instead a virtual steady-state system has been reached which will continue to graduate slightly more than 30 doctorates in electrical engineering per year. Attempts either to modestly increase or decrease this total are not likely to result in any major economic savings or expenditures within the universities.

To date all doctoral graduates have been able to find employment. Projections of demand, within the limitations that such estimates can be made, do not indicate a serious imbalance with supply. If attempts are to be made to adjust the supply it is not clear whether these adjustments should be to increase or to decrease the supply. It appears that the social consequences to Canada of an undersupply would be much more serious than the social consequences of an oversupply. Finally, the relevance of the field of specialization of the doctoral research to the interests of prospective employers will influence the demand.

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CHAPTER 3

FACTORS TO CONSIDER RELATING TO THE DOCTORAL PROGRAMME IN ELECTRICAL ENGINEERING

Excellence

It is our position that it is in Canada's interest, especially in international competition, to have strength in high-technology research and development in electrical engineering. In acquiring and maintaining this strength, high standards of excellence with emphasis on quality rather than quantity will pay off in the long run. The administration of PhD programmes in electrical engineering in Ontario must always aim at excellence.

Critical size for faculty interaction

The organization of a successful department with 10 to 20 professors is a profound operation requiring luck as well as skill. The department may be one of excellence if there is reinforcement due to a grouping of interests and abilities so that the impact from the group operation exceeds that possible from the sum of the individual professors. There is little agreement on the number of faculty members necessary for this to happen, the so-called critical size. Perhaps 10 to 20 faculty members are necessary.

There are those who believe that a professor can successfully work in isolation. While this seems possible, its occurrence is a rare event. In the visits of the consultants to the eight universities in Ontario with PhD programmes in electrical engineering, we observed no faculty member working in isolation from all others!

How many areas should a relatively small department attempt to cover? To restrict all activity to one area alone is questionable wisdom. Under such circumstances, it seems unlikely that PhD students will receive the breadth that is needed. In the range of 10 to 20 faculty members that we have suggested, there should be two to three well-chosen areas in a department. By "well-chosen", we mean that the areas should provide the breadth needed by the students and at the same time result in reinforcement. Two or three of the following seem to constitute good choices: systems (communications or control), computer, solid-state devices. For the size considered, more than three areas will generally result in splintering of a faculty.

Critical size for student interaction

An observation is that the number of students working for the PhD degree approximately equals the number of faculty members.

For the size of department under discussion, that means that there would be 10 to 20 students enrolled. This may be the minimum at which there will be the combination student-student and student-faculty interaction as well as student-student reinforcement necessary for a good graduate programme. It should also be recognized that reinforcement is "students learning from students". This important mechanism should be recognized and encouraged - through seminars, arrangement of offices for students, perhaps even social activities.

Interaction with industry

It is a common observation that a graduate programme benefits from proper student and faculty interaction with industry. A "proper" interaction results when the interaction is of mutual benefit in terms of equipment or expertise, when it is confined to reasonable percentages of time spent "visiting", and when it is carried out in an area of high technology at the forefront of research, rather than in the later stages of development.

Relationship to undergraduate programme

While the production of experts for Canadian industry is important, we should not lose sight of an equally important reason for gradu te programmes; a means by which faculty can remain well informed and current in the teaching of undergraduate students. In addition, research facilities can often be used by undergraduate students. It is difficult to conceive of an undergraduate programme of excellence in isolation from a quality graduate programme.

Foreign students

An ideal graduate programme will bring together students with a variety of backgrounds, coming from various universities, with a variety of experience that can be shared. This sharing is one component of strength of a department in its graduate offerings. For the same reasons, it is desirable to have some students from foreign countries as graduate students, as well as to satisfy national commitments. Students from any one non-Canadian background should be in a minority. It is generally agreed in U.S. universities that foregin students should not exceed about 25% of the graduate student body; this would seem to be a reasonable long-range goal.

Field of specialization

There is observed both in Canada and in the U.S. what might be termed a "first-job syndrome". Employers tend to hire new graduates exclusively on the basis of their area of specialization, their thesis research. Unfortunately, this specialized area of competence at the time of graduation appears to be more important in hiring practices than general intelligence. The second job may well depend more on abilities and breadth of interests. In terms of placement of graduates, this "first-job syndrome" cannot be ignored.

In more practical terms, the education of PhD students in areas of national need is more efficient use of resources than is a random choice of fields followed by a period of retraining. If areas of national need can be identified, then this information should be made available to students, as well as to faculty members, to aid in the selection of areas of PhD research.

Relevance to Canadian Needs

The utilization of electrical engineers in Canada at the doctoral level will be influenced by national political decisions. To date, extensive government studies have emphasized areas which are closely related to the electrical engineering profession. A major study of the future of telecommunications has been summarized in the publication Instant World.[1] The future needs and implications of computer-communications have been studied by a large government-sponsored task force. Their findings appear in two volumes[2] entitled Branching Out. Government attention and possible action in the areas of communications and computers is contained in the two documents[3,4] Proposalr for a Communication Policy for Canada and Computer/Communication Policy. Extensive emphasis is being placed on studies related to energy in Canada. The Department of Energy, Mines and Resources has recently published their study[5] and a further study sponsored by the Science Council of Canada[6] is scheduled to appear early in 1974.

Overall, as viewed from the electrical engineering profession, there are reasons to be encouraged by the areas that have been selected as important for policy decisions. It is clear that future activities and implementation of programmes in these areas will provide opportunities for electrical engineers at the doctoral level.

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1 Instant World (A Report on Telecommunications in Canada), Information Canada (1971)

2 Branching Out (Report of the Canadian Computer/Communications Task Force), Dept. of Communications, May (1972)

3 Proposals for a Communications Policy for Canada (A Position Paper of the Government of Canada) (1973)

4 Computer/Communications Policy (A Position Statement by the Government of Canada) (1973)

5 An Energy Policy for Canada - Phase 1 - Analysis (1973)

6 Science Council of Canada Special Study headed by Dr. G.N. Patterson

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CHAPTER 4

EVALUATION OF THE DOCTORAL PROGRAMME IN ELECTRICAL ENGINEERING IN ONTARIO UNIVERSITIES

4.1 The Nature of the Doctoral Programme

There is some measure of uniformity in the requirements for admission and graduation for the eight universities visited. These requirements will be summarized, and some exceptions to the general rule noted.

(a) Entrance standards. Admission to the PhD programme normally takes place at the time the master's degree is received, and is based on academic record to that time plus demonstration of research ability. The graduate calendars sometimes indicate that a minimum grade average of B is required or sometimes this is merely implied. This procedure probably works well because of the small number of students involved, and the fact that a thesis is required for the master's degree. On the other hand, there is some indication that grade averages are too low, and that standards should be raised. In particular, it is recommended that students entering the PhD programme should ordinarily have first-class honours in addition to showing promise in research.

(b) Qualifying examination. All of the eight universities make provision for a qualifying examination, and all have such an examination with the exception of the University of Ottawa. This examination is normally conducted in the first year of residence in the PhD programme. It may include the presentation of a seminar in addition to or in lieu of the written examination, and a report on the proposed thesis research is sometimes required, separately or as the subject for the seminar. As is common at all universities, there is dissatisfaction with the nature of the examination, amongst both faculty and students, and most schools experiment with new approaches.

(c) Thesis requirements. All eight universities require a thesis of original work, presented in proper format, and an oral defence of the thesis. All require an outside examiner, and all give evidence of care in the selection of an appropriate outside examiner.

(d) Seminar requirements. There is great variation between departments in the extent to which doctoral students are required to participate in seminars. The requirements range from none at all at Queen's to a very structured seminar programme at Windsor. At Toronto, there are variations between groups and there is apparently no organized departmental seminar programme in which student participation is expected. It is suggested that the presentation of seminars should become a formal component of doctoral programmes.

(e) Qualification of supervisors. Waterloo, Toronto and Carleton, have formal qualifications for a supervisor of PhD research. These involve either the supervision of master's degrees, or assistance to senior members of the faculty with doctoral supervision. At the other six universities, requirements are not spelled out, although they may be operating informally. It is suggested that it is good practice to institute some requirements for qualification as an aid to newly-appointed faculty members and for the protection of their students.

(f) Duration of time in residence. The formal residence requirements at the eight universities are for a minimum of three years beyond the BSc and not more than seven. Time limits where they exist may be too long, and there appears to be evidence that the rule is not always enforced.

(g) Course requirements. With the exception of the University of Waterloo, there are formal course requirements beyond those required for the master's degree - ordinarily four courses, but sometimes as many as six.

4.2 The Doctoral Students

A high point of each of our visits to the institutions was the session with the doctoral students themselves. Where faculty members in individual interviews generally tended to be constrained in their remarks, the students in group sessions were extremely forthright, exposing both weaknesses and strengths in their schools. In most instances, their statements confirmed opinions reached on the basis of data previously available, but in some cases they prompted us to look more closely at details that might otherwise have been missed.

The conclusions reached with the help of their remarks appear in other sections of this report; here we propose to look at the characteristics of the group as a whole.

Origins

In most of the Ontario universities, doctoral students in electrical engineering are a very cosmopolitan group, with members from all parts of the world. This is apparent from Figures 4.1 and 4.2 which show origins of doctoral students by country of first degree and by immigration status, respectively. Over the period 1969-73, the percentage of all doctoral students with first degrees from Canadian universities has been consistently in the range 47-51%. On the other hand, among part-time students more than 60% are from Canadian institutions. In terms of citizenship status, during the same period from 43% have been Canadian citizens. It is relevant to note that the decrease in enrolment over the last two years has been primarily in the Canadian-trained or Canadian-citizen groups. The other components of the population have not changed as dramatically.

Turning now to the distribution of origins by institution, there are pronounced differences, as shown in Figure 4.3, which refers only to the doctoral population in 1972-73. In that figure, distinctions are drawn between

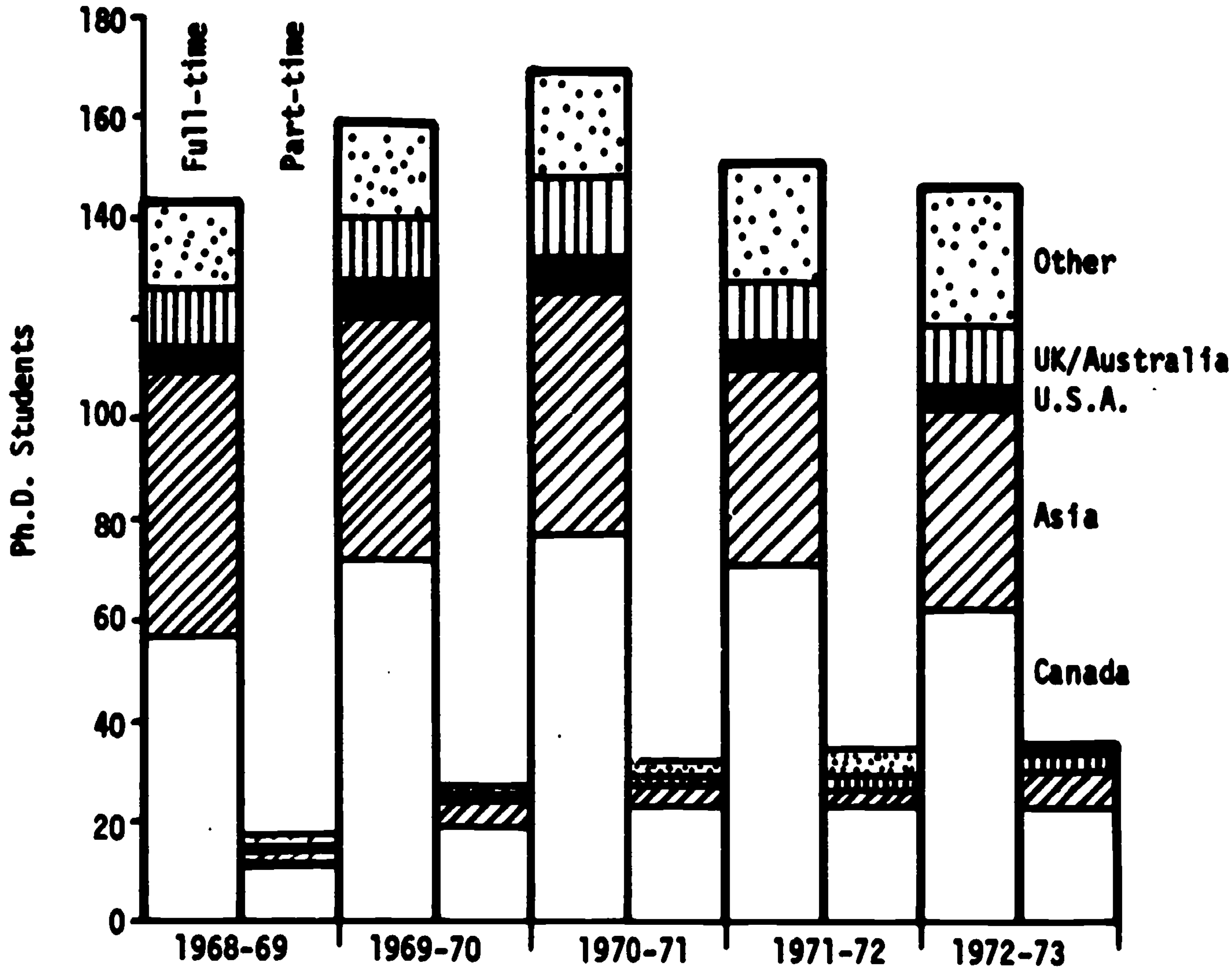


Fig. 4.1 Ph.D. students by country of first degree

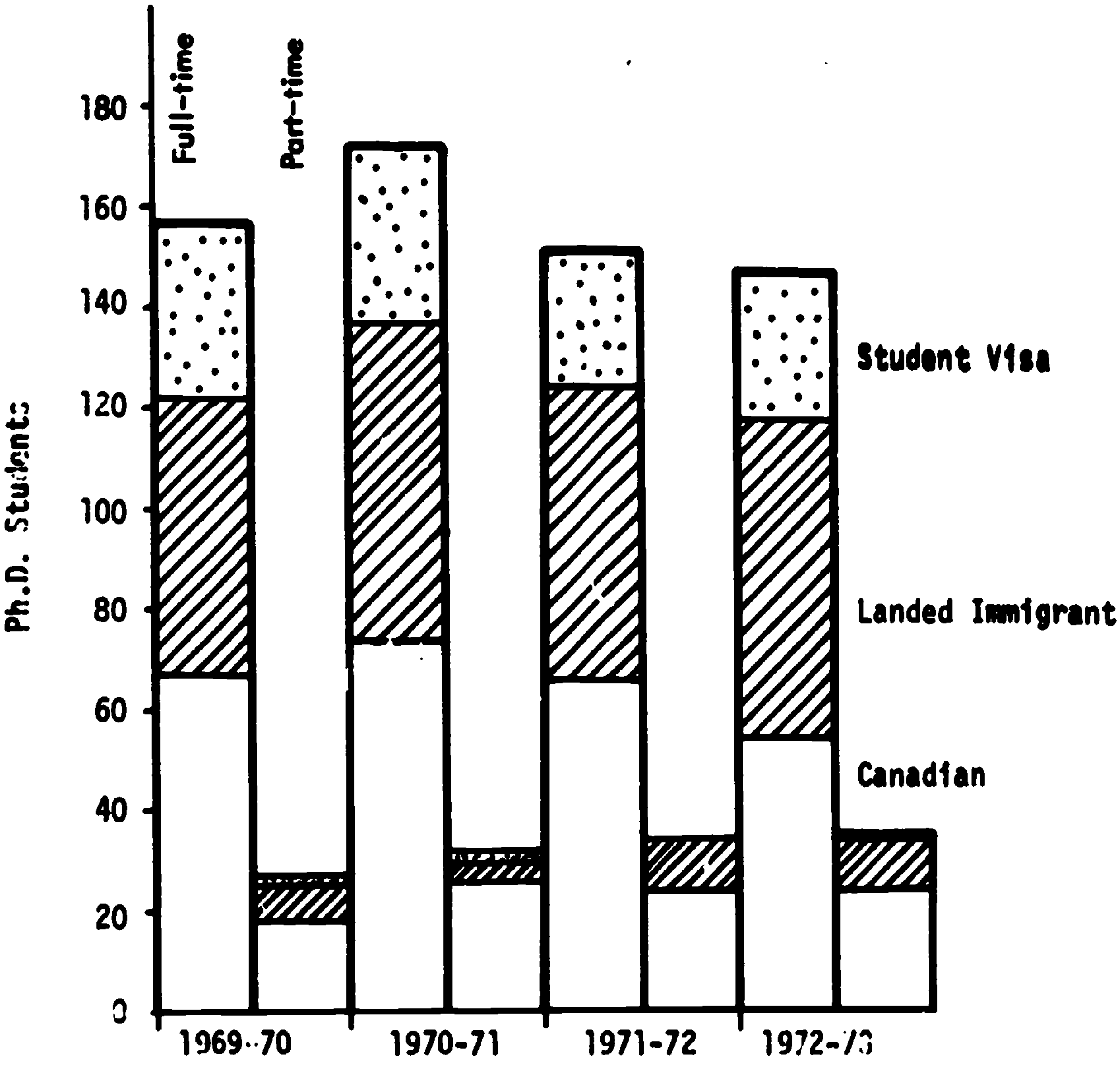


Fig. 4.2 Ph.D. students by immigration status

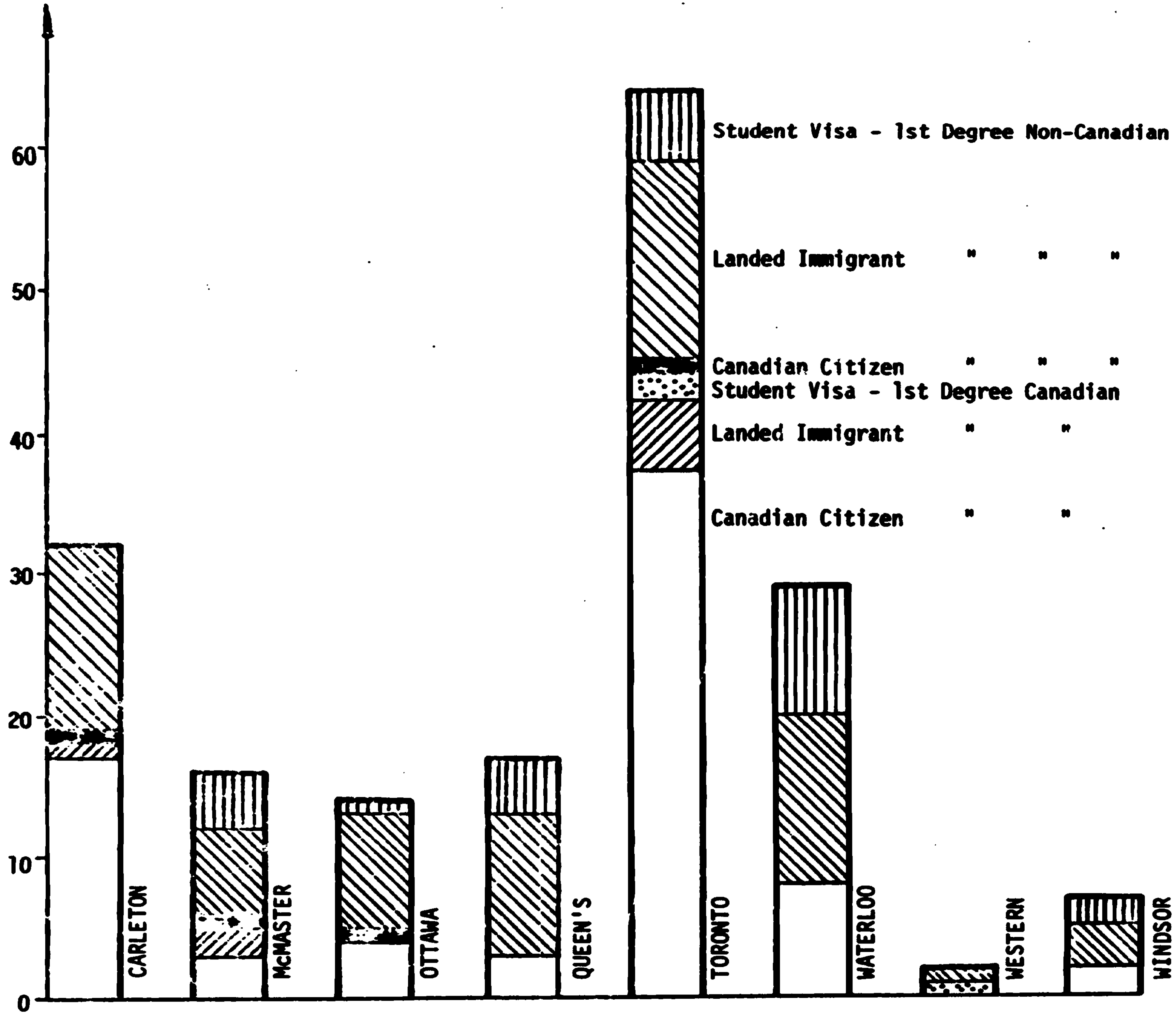


Fig. 4.3 Immigration status - E.E. doctoral students - by institution - 1972-3

Canadian citizens, landed immigrants and those on student visas as well as between those with Canadian and non-Canadian first degrees to distinguish between those who have previously been in Canada and those whose entry to a graduate programme may have coincided with first entry to Canada. Those in the landed immigrant and student visa categories (with non-Canadian first degrees) are in the latter group. It is quite evident that Toronto and Carleton have strong doctoral programmes based on Canadian or Canadian-trained students alone. The low Canadian component is noticeable at all other institutions. There may be one mitigating factor to be noted, however; all departments but that at Western have graduate students supported by the Canadian International Development Agency (CIDA) or by their own governments. The data available for 1972-73 does not separate master's and PhD students, but the institutions affected and total numbers of students are Carleton - 2, McMaster - 1, Ottawa - 1, Queen's - 5, Toronto - 11, Waterloo - 7, and Windsor - 2. A further point to be noted is that at Carleton University, where part-time doctoral students are in the majority, though 80% of part-time doctoral students in 1972-73 were Canadian or Canadian-trained, only 25% of full-time students were in that category. Toronto therefore stands out as the single institution in the Ontario system predominantly Canadian in its electrical engineering graduate student origins, though Carleton has the counterbalance of Canadian part-time students.

We have serious reservations about the admission policies of most departments with respect to the proportions between Canadian and foreign-trained doctoral students.

Some Enrolment Factors

To put on record the distribution of part-time enrolments in the Ontario electrical engineering departments, we present Figure 4.4, where the fraction of graduate students enrolled part-time in the five-year period 1968-73 is displayed. In that period, only Carleton had more than 15% part-time doctoral students, and at Carleton the figure was 54%. Carleton also had the highest part-time enrolment factor (55%) among master's students, followed closely by Ottawa with (46%).

Also of interest is the "dropout" factor, i.e. the proportion of students who leave during each year for reasons other than completion of the degree. The data for the period 1968-72 shows that on the average 7% of full-time electrical engineering doctoral students drop out during a year. On the other hand, during the same period there were no drop-outs of part-time students except at Carleton, where the rate was 25%. This leads us to suspect that, at all schools but Carleton, the part-time enrolment is composed largely of students who have completed all requirements but the dissertation. We also note that Ottawa, Queen's and Western had no dropouts in that period, a somewhat unusual occurrence in doctoral programmes.

Financial Support

The principal sources of support of graduate students at either the master's or PhD level have been major scholarships, CIDA or foreign government support,

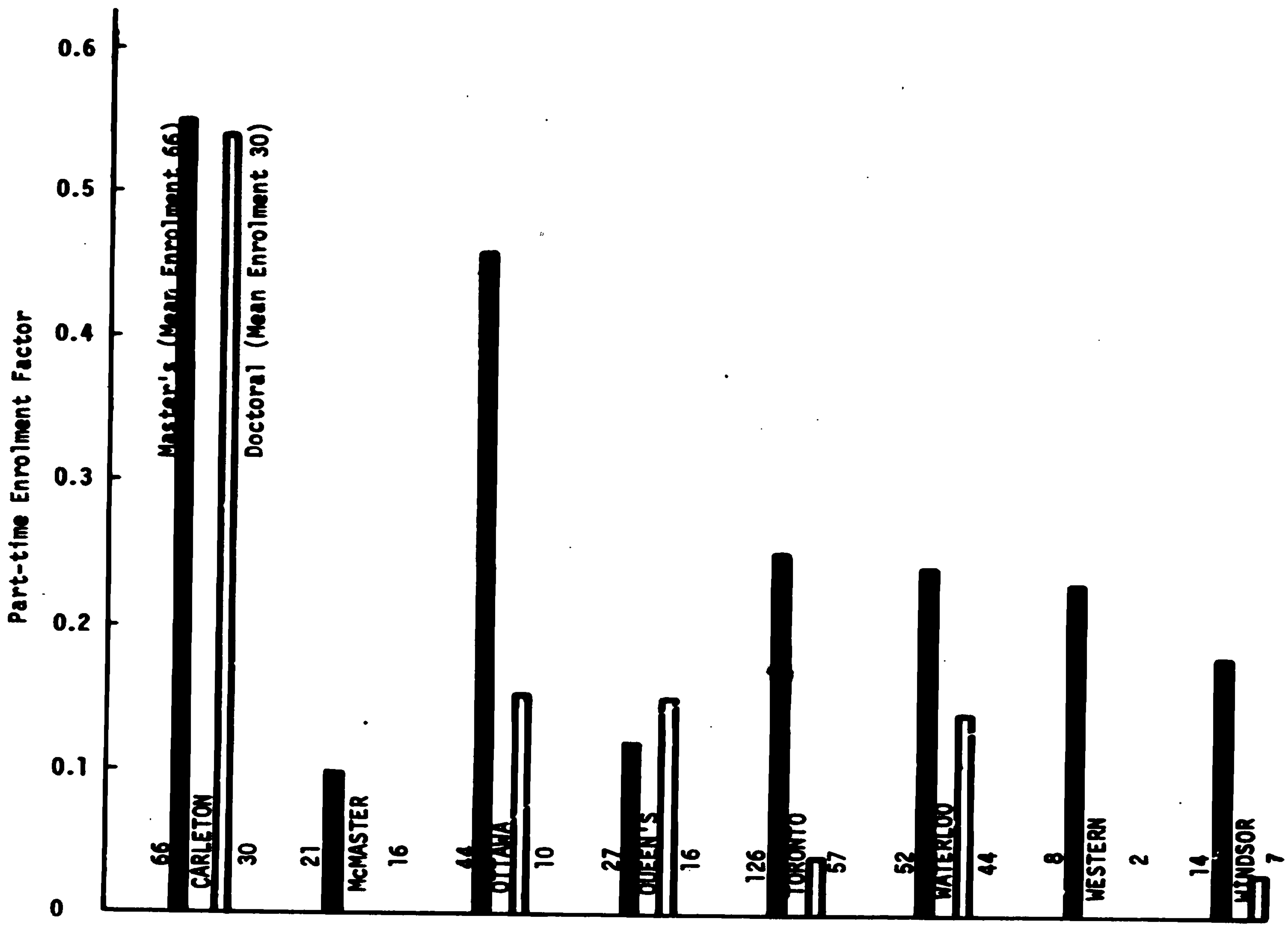


Fig. 4.4 Proportion of graduate population enrolled as part-time students by institution - 5-year average to 1972-3

research assistantships and demonstratorships. Both NRC scholarships and research assistantships supported by federal agencies have become limited to Canadians and to landed immigrants during the last five years. Nevertheless, as shown in Figure 4.5 there has been little change in the pattern of support of graduate students over that period. The data available does not enable us to separate information about master's and PhD students, nor to correlate immigration status and method of support. We can only surmise that there remains sufficient flexibility in the allocation of demonstratorships, internal scholarships, and other funds controlled by the institutions to ensure support for students coming from outside Canada.

The institutional patterns of student support are presented in Figure 4.6. The striking contrast between Toronto and all other schools in its high proportion of scholarship support deserves comment. More than 53% of the graduate-student years at Toronto during the review period have been scholarship-supported. The nearest competitor is Carleton with 28%, and Waterloo has a surprisingly low level of 14%. In the period, 82.5% of full-time students at Waterloo have been supported by research assistantships or demonstratorships.

It should be noted that every full-time graduate student at both Waterloo and McMaster received financial support during the period 1968-72.

To make a further comparison of the electrical engineering departments at different institutions, we have analyzed the distribution of NRC scholarships awarded or renewed during the same period, both on an absolute and a pro rata basis, as shown in Figure 4.7(a) and (b). As might be expected, Toronto shows a significantly higher total than any other school, with 60% of the total awards.

The normalized distribution of Figure 4.7(b) indicates that Toronto still leads by a large margin, with over 35% of student-years supported by NRC awards. The mean level for the Ontario schools is 17.6% and Carleton, Queen's and Windsor lie at or above the mean. Waterloo, Western and Ottawa apparently have little success in attracting NRC scholarship winners, with less than 10% support.

Time to Complete the Doctorate

The time to complete the doctoral programme may not be a fair indicator of student capabilities, either individually or collectively. Nevertheless, in those institutions which have produced enough doctorates to provide a sample of adequate size, a pattern of prolonged doctoral studies can be taken as an indicator of inadequate input standards, insufficient supervision, poorly-chosen research objectives, unrealistic demands on the student, or a combination of those. We shall analyze the Ontario scene in terms of the students, not only because student capabilities are a factor, but also because the years of doctoral study are a significant fraction of students' lives. The data available to us about elapsed time are quantized, so the results should not be interpreted to be precise measures. Moreover, we have no data available concerning

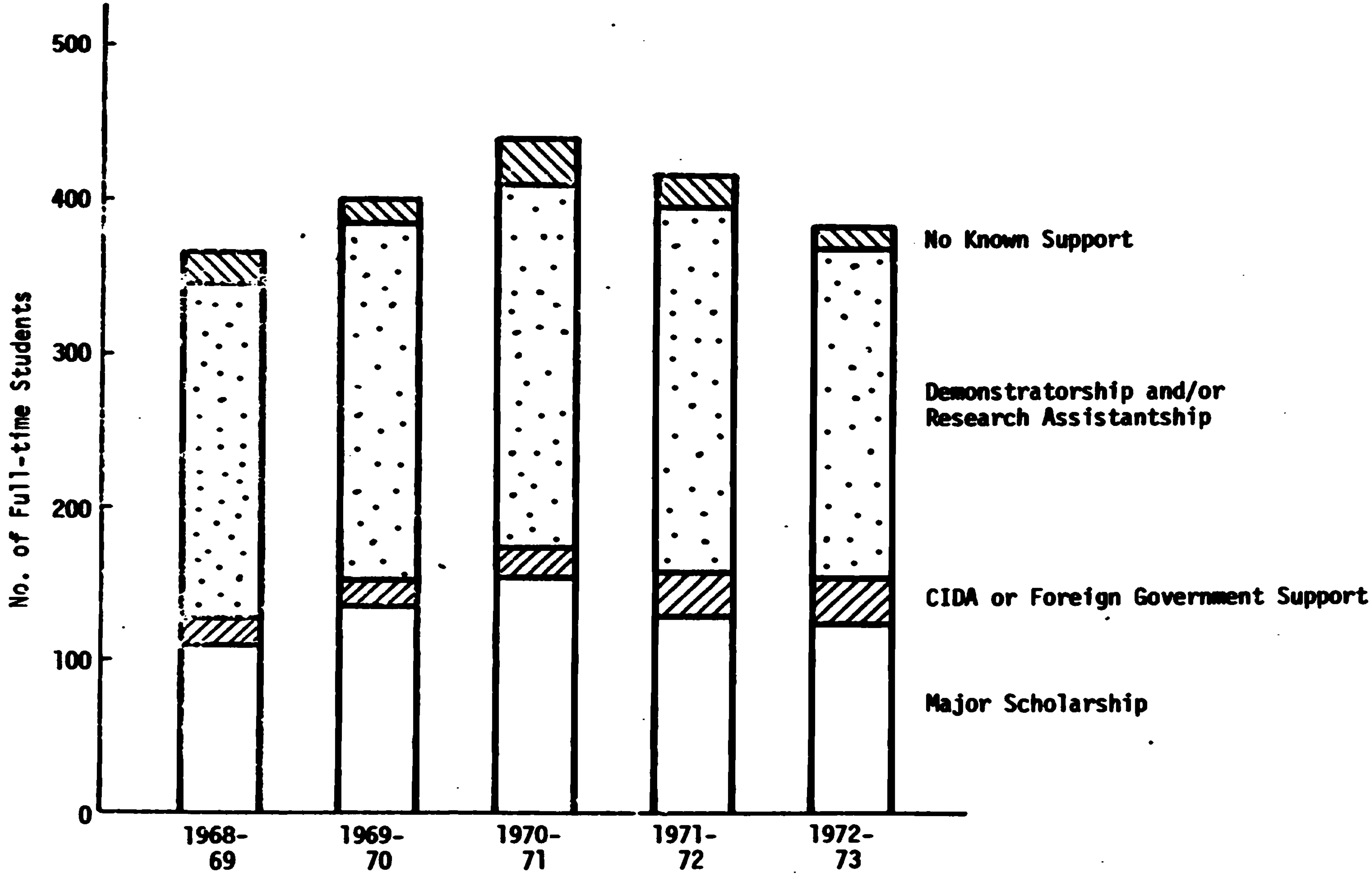


Fig. 4.5 Sources of support - full-time E.E. graduate students - Ontario

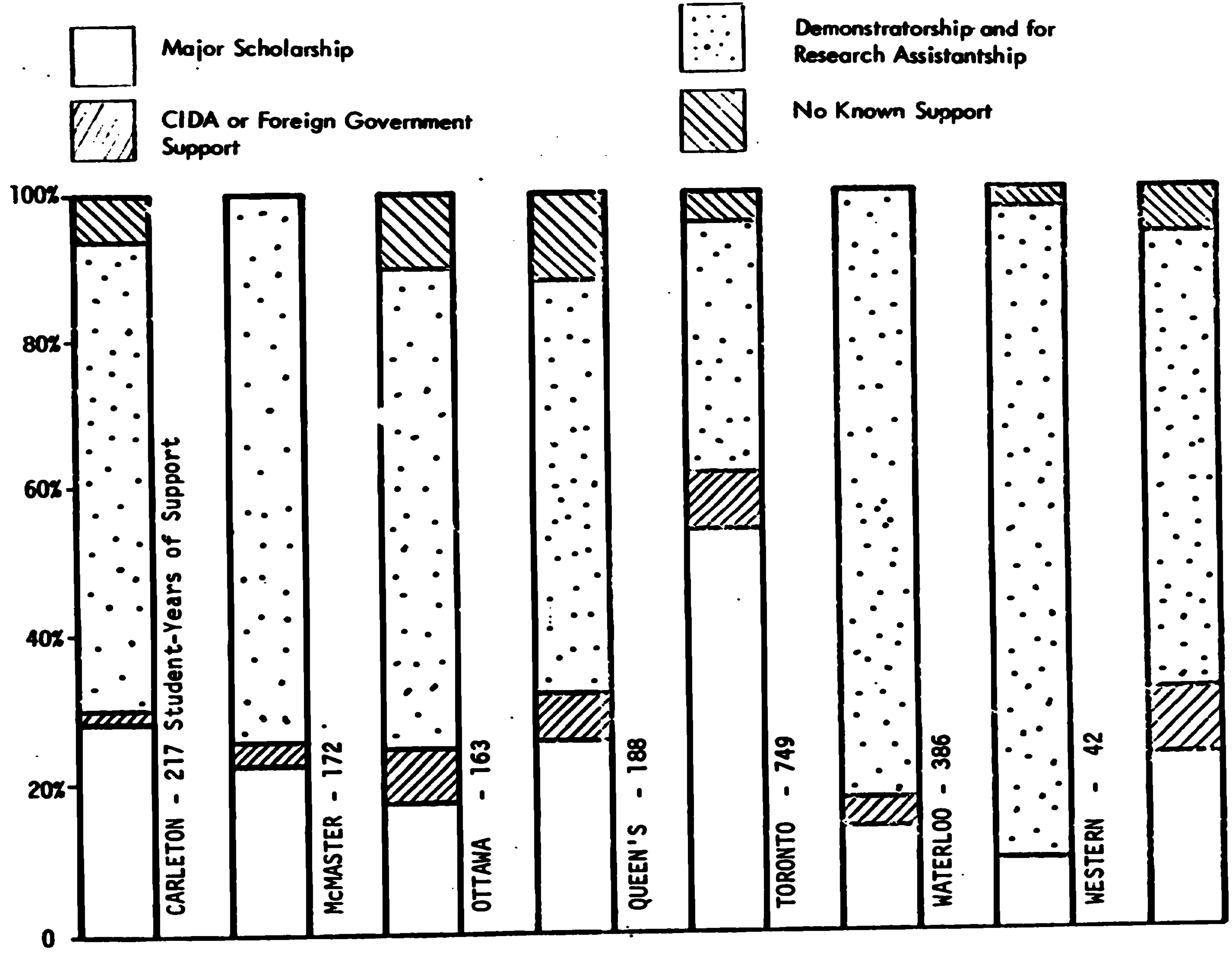
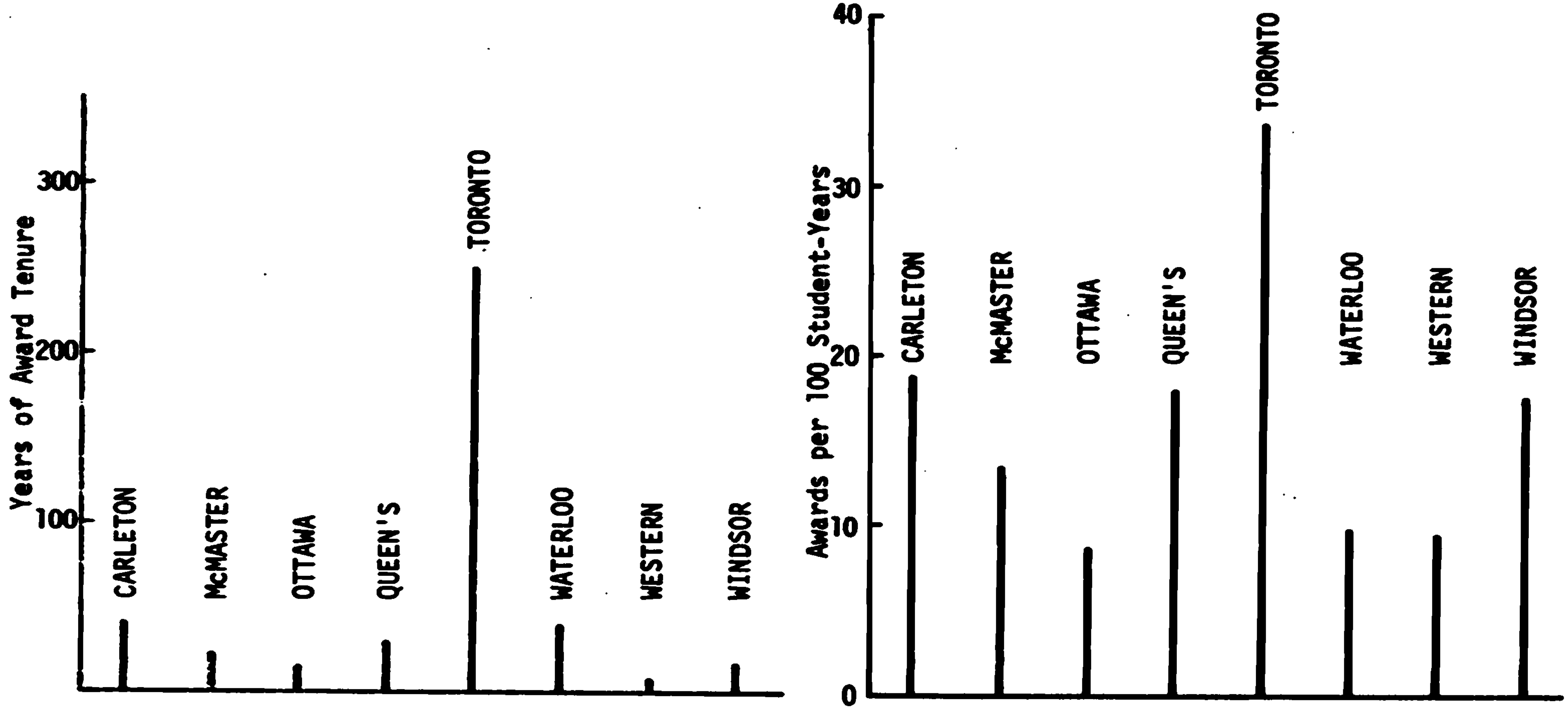


Fig. 4.6 Sources of support - full-time students - by institution
(5-year totals - 1968-72)



(a) Distribution of Awards

(b) Normalized Distribution of Awards

Fig. 4.7 NRC Scholarships awarded or renewed - 1968-72 leaves of absence. Averages have been calculated for degrees completed in the period 1968-73 for two groups of students in each case, (1) those who completed both master's and PhD at the same institution with no absence between master's and PhD work, and (2) those who entered the doctoral programme having completed the master's degree at another institution, or at the same institution but after an absence of more than nine months.

The average elapsed time to completion for those two groups is plotted in Figure 4.8. The average elapsed time from the baccalaureate for all universities is five years, and that from the master's degree (for a different group of students, of course) is four years. In several cases, the number of students involved is not sufficient to enable us to draw conclusions.

The contrast between the results for Toronto and Waterloo are significant, in our opinion. The average Waterloo student takes 13-20 months longer to complete the doctorate than his equivalent at Toronto!

This fact would appear to correlate with our observation that scholarship students are relatively more numerous at Toronto than at Waterloo. The data available to us indicates, however, that at Toronto there is an upward trend in the elapsed time for those who complete both degrees in that department, with no corresponding trend for those who have entered with the master's degree already completed. Ottawa has shown an upward trend for those who have entered with the master's degree.

With reference to the whole Ontario system, we must comment that the average period of doctoral study seems excessive.

Student Interactions

The consultants have attempted to assess the extent to which department and group size and composition affect the development of doctoral students. It was quite apparent that at Toronto, and to a lesser extent at Waterloo, the intellectual stimulation that should be provided in a broadly-based research environment were negated in part by the insularity of research groups. Some of those research groups appear to be virtually self-sufficient, operating their own course sequences and seminars with little outside interaction. At Toronto in particular, it seemed true that student interaction between groups is at a low level. Our fear is that the lack of contact between students in related fields inhibits the development of flexibility. There were also indications that students whose native tongue is not English, especially the Asian students, tend to form isolated pockets, either within a research group or in a department. In our opinion, both of these trends should be discouraged, and every attempt should be made, through departmental seminars or other means, to treat students as equal contributors to the total departmental research effort. We would emphasize that we are not advocating the elimination of groups; rather we deplore the attitude that groups should be self-sufficient. Though the degree of isolation was not so noticeable in the smaller departments, it was felt that in situations in which there is a single student in a research field, special attention must be paid to interaction with other students.

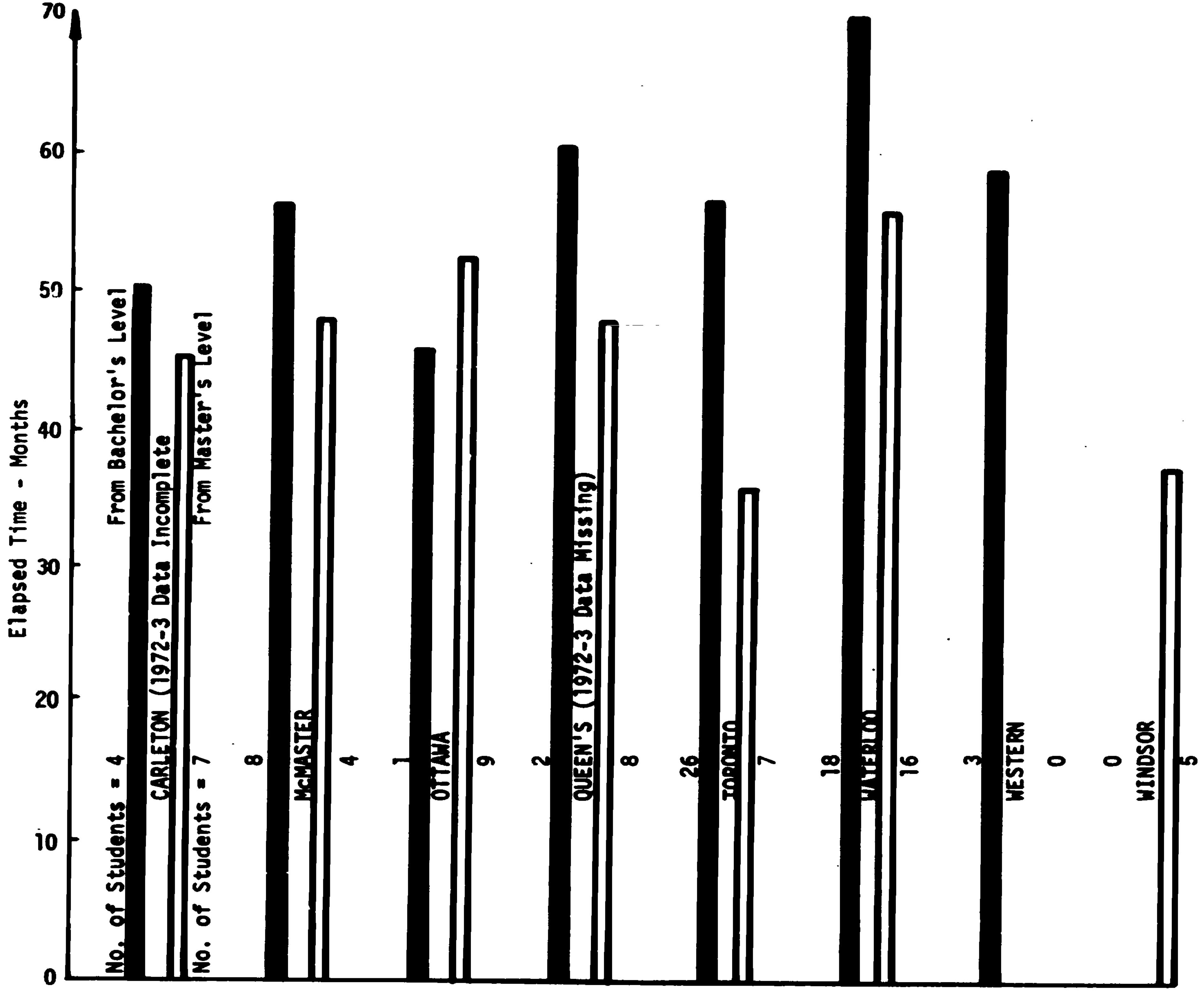


Fig. 4.8 Average elapsed time to complete doctorate by institution - 1968-73

The consultants noted with some surprise the apparent dearth of entrepreneurial aspirations among the doctoral students interviewed. Career objectives seemed more directed towards research or teaching, although realizing the low probability of the latter; some felt they had administrative capabilities.

It would not be fair to say that all students interviewed were satisfied with their programmes. There were complaints, apparently legitimate, that some had been misled in terms of advertised research capabilities of departments, relevance of research fields to the job market, competence and continuity of research supervision. Both complaints and words of praise have influenced our comments in other sections of this report.

In summary, we believe that the electrical engineering doctoral student population in Ontario is of quality comparable to that throughout North America. However, we would encourage efforts to raise that standard.

Today's graduate needs flexibility to adapt to the rapid changes in technology. This requires a critical balance between breadth and depth in the doctoral programme. We suggest that it will be to the long-term benefit of the students if the electrical engineering departments in Ontario recognize these factors.

4.3 Faculty

This section will be concerned with the composition and characteristics of the faculty members of the electrical engineering departments in the Ontario universities, both collectively and by institution. An attempt will be made to point out those factors that might be considered relevant to the pursuit of engineering research and the supervision of doctoral programmes. This task is made difficult in some instances because the data provided by the universities is not completely consistent in its identification of the individuals who should be counted as "members" of a department. In other cases it has been necessary for the consultants to make arbitrary allocations. Cross-appointments, part-time professors and visitors add to the confusion. The counts, therefore, will not always be consistent.

Particular mention must be made of the faculty count in electrical engineering at the University of Western Ontario. Our terms of reference direct us to carry out an assessment in the specific field of electrical engineering. We believe it would be out of order for us to include in our analysis those members of faculty whose contribution to the doctoral programme, valuable though it may be, is not primarily in electrical engineering.

The distribution of faculty by rank in each university in Ontario is shown in Table 4.1. It will be noted that the largest number is at the Associate Professor level.

TABLE 4.1 - NUMBER AND RANK OF FACULTY

	Full Prof.	Assoc. Prof.	Assist. Prof.	Lecturers	Visiting Prof.	Visiting Lect.	Part-Time Prof.	TOTAL
Carleton	4	14	3					21
McMaster	8	3	5				2	18
Ottawa	2	7	5					14
Queen's	2	6	8		1		1	18
Toronto	15	21	6				2	44
Waterloo	10	18	6		3			37
Western	2	2	3					7
Windsor	4	1	3					8
TOTAL	47	72	39		4		5	167

The age distribution (as of December 31, 1972) is displayed in Table 4.2. The median age for all universities is in the late thirties and no single university departs radically from that pattern. Retirements to be expected before 1978 represent about 5% of the present complement of 167. All universities but Queen's have faculty members under age 30.

Of the total number, 134, or more than 80% hold the doctorate. The origins of that group are shown in Table 4.3 in terms of the source of bachelor's and PhD degrees. Canadian baccalaureates are held by 60% of those faculty members, and first degrees from Ontario schools by 39%. Only 5% of the electrical engineering professors with doctorates in Ontario originally graduated in the U.S. and 17% in the U.K. The proportion of doctorates earned in Ontario is 28% and in Canada is 35%, while 26% were earned in the U.S. and 30% in the U.K. Those who have earned both degrees in Ontario number 12% of the total, and both degrees in Canada, 26%. Approximately 75% earned both degrees in Anglophone countries.

The indicators that we have chosen as possible measures of the overall professional experience and maturity of the professorial staff of a department relevant to doctoral programmes are the averages depicted in Figure 4.9(a) - (f). We do not propose to indicate their relative importance, but certainly master's and doctoral supervisions completed, grants and publications are most directly relevant, although post-baccalaureate non-academic experience and patents may be indicators of orientation towards applied research. Departments in the eight universities do not differ radically in average experience, all lying in the range 3-7 years per faculty member. McMaster leads all others in rate of publication by a good margin, with Waterloo second, and the rest very nearly tied. Western and McMaster lead in average number of patents per faculty member, where all but Ottawa and Windsor make a showing.

The average number of master's thesis supervisions completed exceeds four in all schools, and Toronto and McMaster have significantly larger counts. At the doctoral level, average number of PhD supervisions completed per faculty member is comparable at Carleton, Toronto, Waterloo, McMaster and Windsor. Ottawa is in the lowest position, with Queen's and Western only slightly above. On the other hand, in average NRC, MRC and DRB operating grants per faculty member Toronto is in the lead, and Ottawa and Western place last. Note that in supervisions completed at both levels, in publications, in patents and in grants, Toronto is consistently in the upper group of universities. In publications, experience, grants and doctoral supervisions completed, Ottawa is in the lower group. Queen's, although low in supervisions at both levels, in publications, patents and experience, is high in grants.

The distribution of grants within a department shows in some measure the extent to which senior faculty are remaining active in research. That information is displayed in Table 4.4.

TABLE 4.2 - AGE DISTRIBUTION OF FACULTY

(As of December 31, 1972)

University \ Range of Age	<25	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	>65	TOTAL
Carleton		1	6	9	2	2		1			21
McMaster		1	3	6	1	6		1			18
Ottawa		1	2	3	2	3	3				14
Queen's			5	7	3		1		1	1	18
Toronto		3	11	7	8	7	2	3	3		44
Waterloo		2	6	12	7	5	2	1	2		37
Western		1	1	1	1	1	1		1		7
Windsor		1	2	1	1	2			1		8
TOTAL		10	36	46	25	26	9	6	8	1	167

TABLE 4.3 - DEGREES HELD BY FACULTY

Province/Country of Bachelor's Degree - Province/Country of Ph.D.

Bachelor \ Ph.D.	Ontario	Rest of Canada	U.S.A.	U.K.	Other	TOTAL
Ontario	16	1	13	9		39
Rest of Canada	10	8	6	6	1	31
U.S.A.	1		6			7
U.K.	2			21		23
Other	8	1	10	4	11	34
TOTAL	37	10	35	40	12	134

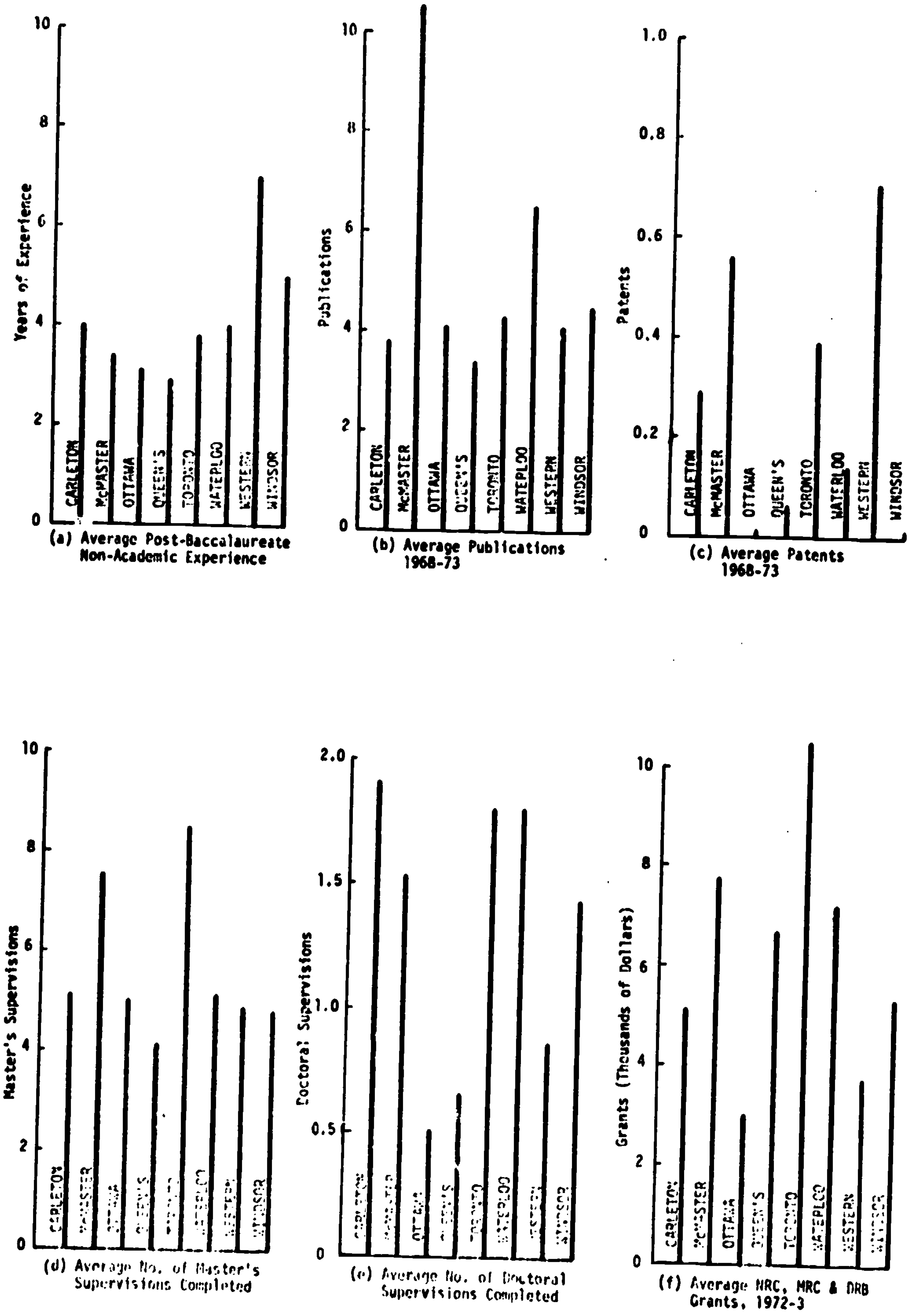


Fig. 4.9 Average faculty characteristics - Ontario E.E. Departments

TABLE 4.4 - DISTRIBUTION OF NRC, MRC AND DRB OPERATING GRANTS (1972-73)

(Visitors, Part-time and Cross-appointments not counted)

University	Number of Faculty with Grants 1972-73 (Grants in Thousands of Dollars)												Total Number With Grants	Total Number of Faculty
	Professors				Associate Professors				Assistant Professors					
	>20	12.5-20	7.5-12.5	<7.5	>10	7.5-10	5-7.5	<5	>10	7.5-10	5-7.5	<5		
Carleton	1	0	0	1	1	3	2	2	0	0	0	3	13	21
McMaster	3	1	2	0	1	1	0	0	0	0	1	1	10	15
Ottawa	0	1	1	0	0	0	1	1	0	0	0	2	6	14
Queen's	1	0	0	0	1	1	0	1	1	0	2	4	11	16
Toronto	4	3	1	0	8	2	5	1	1	0	0	3	28	36
Waterloo	3	4	2	1	4	1	2	5	0	0	1	2	25	34
Western	0	0	1	0	0	0	0	0	0	0	1	2	4	7
Windsor	0	1	1	2	0	0	0	0	0	0	0	1	5	8

4.4 The Research Programme

The discipline group statement (Appendix 2) has listed the major areas of concentration at the doctoral level in the Ontario universities. In summary, those research areas and the number of institutions in which they are offered are essentially as follows:

Devices and Materials	5
Communications	6
Systems	6
Computers	3
Power	4
Electromagnetics	2
Biomedical Electronics	2
Electroacoustics	1
Applied Electrostatics	1
Radio Science	1

For purposes of analysis of the relative strengths of the departments and of the total concentration in each field, we shall take liberties with this list and consider Electroacoustics to be a sub-field of Communications, Applied Electrostatics a sub-field of Electromagnetics and Radio Science to be covered jointly by Communications and Electromagnetics. It will be noted that Electronics as such does not appear in the list; in our collective opinion, "electronics" as a field at the doctoral level is only meaningful either in studies of electronic devices and materials, or as electronic instrumentation applied in another field such as those listed above.

This rather arbitrary decomposition of doctoral programmes has been made in order to be able to quantify some of the data concerning faculty interests, research funding, and doctoral enrolment. Because the information was not all uniformly clear, it has been necessary for us to draw inferences from some of that data that may not be totally justified. As a consequence, there are some inconsistencies in total staff and student numbers, but we believe that the overall pattern of departmental strengths in various research fields is a true representation.

Some idea of the relative strengths of departments and of fields can be obtained from the set of Tables 4.5, 4.6 and 4.7. Examined in terms of present needs of industry and government, it appears that there is too much stress on fields that tend to be theoretical at the expense of experimental and application areas. In particular, there are too many students working in systems and too few in computer applications. In most other respects, the balance is about right - in electromagnetics, in communications, and in devices and materials. In fact, except for the systems area, the eight departments have strengths such that there is a reasonable overall balance without either excessive overlap or duplication.

TABLE 4.5 - FACULTY NUMBERS BY RESEARCH FIELDS (1972-73)

	Biomedical Electronics	Communi-cations	Computers	Devices & Materials	Electro-magnetics	Power	Systems
Carleton	0	3.5	3.5	8.5	0	0	4.5
McMaster	0.5	4	0.5	5	0	1	3.5
Ottawa	0	1.5	4	1.5	1	1	4
Queen's	0	6	1.5	0	0.5	4	4
Toronto	6.4	4.2	5.6	3.7	6.4	9.1	6.6
Waterloo	1	8.5	2.5	8	3	7	8
Western	1	1	0	0	4	1	0
Windsor	0	0.5	1	1	1	3	2.5
TOTALS	8.9	29.2	18.6	27.7	15.9	26.1	33.1

TABLE 4.6 - DOCTORAL STUDENTS ENROLLED BY RESEARCH FIELD (1972-73)

	Biomedical Electronics	Communi-cations	Computers	Devices & Materials	Electro-magnetics	Power	Systems
Carleton	0	10	0	12	0	0	11
McMaster	1	9	0	4	0	0	4
Ottawa	0	1.5	8.5	3	0	0	1
Queen's	1	8	0	0	0	1	7
Toronto	13	4	13	6	5	13	10
Waterloo	0	2	2	7	4	7	7
Western	0	0	0	0	2	0	0
Windsor	0	0	0	0	0	3	4
TOTALS	15	34.5	23.5	32	11	24	44

TABLE 4.7 - RESEARCH FUNDING BY FIELD (1972-73)

(in Thousands of Dollars)

	Biomedical Electronics	Communi-cations	Computers	Devices & Materials	Electro-magnetics	Power	Systems
Carleton	-	86.9	5.0	131.13	-	-	18.6
McMaster	-	59.04	-	141.8	-	3.8	27.0
Ottawa	-	26.58	19.0	11.5	-	-	8.5
Queen's	-	111.57	-	-	70.02	7.45	30.6
Toronto	50.1	17.8	109.75	59.0	36.2	81.6	38.9
Waterloo	-	22.05	12.2	72.6	21.8	49.9	66.05
Western	29.0	-	-	-	65.8	-	-
Windsor	-	-	6.6	6.6	-	28.57	13.8
TOTALS	79.1	323.94	152.55	422.63	193.82	171.32	203.45

Two areas require further comment. Biomedical engineering is a new field which is developing slowly in terms of opportunities for graduates. There should not be a rush to add this specialty to the programmes of universities not already in this field. The capability for producing PhD graduates in power is greater in Ontario than in any other location in North America. The future needs of Canada in power will surely be in energy system dynamics and in improved devices for transmission and utilization.

4.5 Assessment of Universities

Assessments of the individual institutions, particularly their strengths and weaknesses, are contained in Appendix 3. In this section we summarize our impressions of the capabilities of the universities to give doctoral training in electrical engineering.

We have rated the departments of electrical engineering in two ways. The first is with respect to laboratory facilities for graduate research. Here we have considered the adequacy of equipment and accommodation and arrangement of the experimental facilities. The summary of our evaluation is given in Table 4.8, for each of the seven areas that have been selected to represent subdivisions of electrical engineering. Letter grades are given, with an asterisk indicating that the facilities are improving, in our judgment, and should rank higher in a year or two.

Overall the highest rankings for laboratory facilities (as seen in Table 4.8) go to the University of Toronto and the University of Waterloo. In the two areas in which it has strength, high rankings are given to Carleton University. Facilities are not well developed at the University of Ottawa, and the department receives low grades in all areas.

Secondly, we have rated the universities according to our assessment of the capability of the departments to give the PhD degree in electrical engineering, as shown in Table 4.9. In determining these grades, some of the factors taken into consideration were the following:

(a) faculty
(b) facilities (departmental and support)
(c) adequacy of research programmes
(d) adequacy of course and other requirements
(e) interaction with others, both internal and external
(f) administration of programme

Four departments are recognized as having high overall capability for giving the PhD degree: Carleton, McMaster, Toronto, and Waterloo. Windsor is a small department, but well organized for covering the limited number of areas indicated, with good focus on objectives. Queen's is an old department with a distinguished history, but it appears to suffer from geographic isolation and project fragmentation as well as some lack of facilities.

TABLE 4.8 - QUALITY OF LABORATORY FACILITIES -- (NOTE: A > B > C)

	Communi-cations	Computers	Devices & Materials	Electro-Magnetics	Power	Systems	Biomedical	OVERALL
Carleton	A	NIL	A	NIL	NIL	A	NIL	A
McMaster	B*	B	A+	NIL	NIL	A	C	B+
Ottawa	C*	C	C	NIL	NIL	B	NIL	C
Queen's	B	B	B	B	B+	B	NIL	B
Toronto	B	A+	A-	A	A-*	A	A	A
Waterloo	A*	A	A-	B+	A	A	NIL	A-
Western	NIL	NIL	NIL	B+	NIL	NIL	NIL	B+
Windsor	NIL	NIL	NIL	NIL	B+	B	NIL	B+

* Denotes improving.

The specialties covered by the departments within these 7 broad areas are given in Appendix 3.

TABLE 4.9 - CAPABILITY OF GIVING THE PhD DEGREE IN ELECTRICAL ENGINEERING

(NOTE: A > B > C)

	Communi-cations	Computers	Devices & Materials	Electro-magnetics	Power	Systems	Biomedical	OVERALL
Carleton	A	NIL	A	NIL	NIL	A	NIL	A
McMaster	A-*	NIL	A	NIL	NIL	A	B-	A-
Ottawa	C*	B	C	NIL	NIL	B-	NIL	C+
Queen's	B+	NIL	C	B	B-	B+	C	B
Toronto	B+	A+	A	A	A	A	A	A
Waterloo	B+	A-	A	B	A	A	NIL	A-
Western	NIL	NIL	NIL	C	NIL	NIL	NIL	C
Windsor	NIL	NIL	NIL	NIL	B+	B	NIL	B+

* Denotes improving

The specialties covered by the departments within these 7 broad areas are given in Appendix 3.

We have given Western a low grade primarily on the basis of the narrowness of the educational programme in electrical engineering available for its students. The graduates of their programme are not well equipped to compete when they must find employment outside their specialty. Ottawa receives a low rating for the reasons outlined in detail in Appendix 3. The number of faculty in each area is limited, facilities are generally inadequate, and there is relatively little collaboration internally or externally.

* * * * * *

CHAPTER 5

RECOMMENDATIONS

1. Supply and Demand

It is recommended that no limit or quota on production of doctorates in electrical engineering be established for the Ontario universities, but rather that the number of doctorates granted in electrical engineering be determined by:

(i) availability of capable graduate students
(ii) maintenance of adequate standards by the universities, and
(iii) the existing capacity (staff and facilities) of the universities for giving adequate training

2. Relevance of Areas of Graduate Research

Because of the close relationship between the relevance of the areas of doctoral research to potential employer interests and the ability of the graduates to obtain their first job it is recommended that the heads of the departments of electrical engineering

(i) jointly and on an annual basis, identify those areas of research in electrical engineering which they consider relevant to the present and future needs of Canada, and

(ii) put their findings into a report to be made available to the granting agencies and to various associations of industry such as the Canadian Research Management Association, the Canadian Electronics Industry Association and the Canadian Electrical Association in order to stimulate a continuing dialogue with industry.

3. Administration of Doctoral Programme in Electrical Engineering in Ontario Universities

It is recommended that the Ontario universities

(i) tighten the standards for admission to the doctoral programme in electrical engineering to accept only candidates with first class standing and with proven research ability

(ii) establish criteria for qualification of faculty to supervise doctoral theses in those cases where such criteria do not already exist

(iii) administer more rigorously the doctoral programme in electrical engineering, and

(iv) aim to decrease the average time for completion of doctoral degree requirements by one year.

4. Carleton University, McMaster University, University of Toronto, University of Waterloo

It is recommended that these universities be encouraged to carry out their 5-year plans relating to graduate work in electrical engineering, including some modest increase in student enrolment where desired, subject to the constraints contained in Recommendations 1 and 3 and in the analyses of Appendix 3.

5. University of Ottawa

It is recommended that

(i) during the period 1974-78 the University of Ottawa stop accepting new students for the doctorate in electrical engineering but increase its services in continuing education, including full and part-time degree work at the master's level

(ii) a cooperative arrangement be worked out between the University of Ottawa and Carleton University to permit faculty from Ottawa who are qualified to guide doctoral research to become visiting or adjunct members of the faculty at Carleton University or some equivalent arrangement

(iii) more extensive use be made of the arrangement between the University of Ottawa and Carleton University whereby graduate courses taught at either institution are accepted for credit at the other

(iv) the Department of Electrical Engineering be reviewed after a 5 year period to determine whether improvements in administration of the programme, working relations with local industry and government establishments, a better balance between theoretical and experimental research, and improvements in faculty and facilities had been achieved to the point where a doctoral programme should be resumed.

6. Queen's University

It is recommended that the department of electrical engineering at Queen's University

(i) concentrate for the present in the fields of "communications" (including electronic instrumentation and applications of electromagnetics) and "systems"

(ii) remain for the immediate future at its present level of doctoral enrolment

(iii) improve its research facilities in the above fields through a major negotiated development grant or other mechanism, and

(iv) be encouraged to seek more active involvement with government and industry groups in order to overcome its geographic isolation.

7. University of Western Ontario

It is recommended that the University of Western Ontario

(i) cease to offer the doctoral degree in electrical engineering but continue to offer the master's degree

(ii) carry on the research in applied electrostatics with postdoctoral fellows and research associates with the long-term goal of forming a research institute, and

(iii) expand the breadth of courses available in the master's programme with the assistance of postdoctoral fellows and research associates.

8. University of Windsor

It is recommended that the doctoral programme in electrical engineering at the University of Windsor

(i) continue at its present level

(ii) not expand beyond the current fields of "power" and "signals and systems" but place increasing emphasis on the latter, and

(iii) be reviewed after a 5-year period.

9. Coordination of Electrical Engineering Programmes at Ontario Universities

It is recommended that the chairmen and graduate coordinators of all the electrical engineering departments in the Ontario universities continue to meet at frequent intervals, meetings to be held at various institutions rather than the most central, with the aim of

(i) determining areas of specialization for the different electrical engineering schools in the province, and

(ii) coordinating plans for development of new programmes or areas.

10. Support for Foreign Students

Since it has been observed that some foreign students with landed immigrant status have no intention of remaining in Canada, it is suspected that they are taking advantage of the easy financial assistance available in some of the institutions. It is therefore recommended that

> the heads of departments ensure that admission and support practices are not contrary to the intent of Canadian immigration policies.

APPENDIX I

TERMS OF REFERENCE OF CONSULTANTS

1. Consider the two special documents related to the coordination of the assessments in Engineering, viz. Engineering PhD Planning and Assessment Procedures, Statement on PhD Studies in Engineering Studies in Ontario, and the material prepared by the discipline group and the universities and obtain other data they may require to carry out the tasks detailed below. They shall be provided with copies of "Ring of Iron", the COU statement thereon, and the CODE, OCGS and APEO responses. They may obtain data and views from any relevant source, such as, for example, employers of holders of graduate degrees, professional and learned societies, federal agencies. The campus of each interested university shall be visited by at least two consultants. Consultants shall arrange their schedule of visits to the universities in consultation with ACAP to ensure uniformity. Reports of appraisal consultants are privleged documents and are not to be made available to ACAP consultants. Consultants shall meet with the discipline group near the beginning of the work, during the work as they consider necessary, and immediately before preparing their final report.

2. Report on the adequacy of the present state of doctoral work in "electrical engineering" in the province in general and in each university where applicable, discussing the following:

   a. coverage of fields and specialties, and extent of activity in each

   b. faculty quality and quantity

   c. nature of programmes offered

   d. enrolment size and distribution amongst universities and divisions

   e. quality of student body; admission requirements

   f. relationship to related disciplines and to the profession

   g. physical facilities

   h. other matters considered by the consultants to be significant

3. Make recommendations for the development of doctoral work in fields of this assessment in Ontario between 1973 and 1978, taking into consideration such plans as may be developed by the Discipline Group, and, without limiting the generality of the foregoing, dealing with the following points:

   a. Desirable doctoral programmes to be offered in the province, considering both possible limitations or reductions of existing programmes and creation of new programmes and new kinds of programmes including the appropriateness of part-time programmes. In particular, consider if there should or should not be more activity in fields now producing few graduates in Ontario and also the desirability of developing further application-oriented and inter-disciplinary work and industrial involvement.

b. Desirable provincial enrolments, year by year, in the doctoral study in electrical engineering and in the major subject divisions where appropriate. One should consider the need for highly trained manpower and also the general cultural and societal factors which may lead students to pursue doctoral work in engineering. In considering manpower needs, one should take account of the "market" available to graduates (at least all of Canada) and of other sources of supply <u>for that market</u>. Results of forecasts of high level manpower employment should be treated with due caution and only in a clearly balanced relationship with cultural and societal needs.

c. Distribution amongst the universities of responsibility for programmes and for specialties where appropriate, including consideration of the need for any increase or decrease in the number of departments offering doctoral work and including consideration of areas of collaboration and sharing of facilities at regional level and across the province. Consider techniques for involvement in doctoral supervision of professors in departments which do not take doctoral students in their fields, and the extent to which such activity is desirable.

d. Distribution of enrolment amongst the universities, showing desirable <u>ranges</u> of enrolment.

In all cases, it is important that the rationale for the recommendations be clear; this is especially important for items c. and d.

4. It is permissible for consultants to recommend appraisals of individual programmes. This would arise if consultants were to suspect that a programme would be found to be wholly or in part below minimum acceptable standards; and appraisal by the Appraisals Committee is the means of settling the question. It is recognized that this action would be infrequent. In carrying out planning assessments in some disciplines, consultants find there to be an excess or deficiency of programmes in a given area of study, where all of the existing programmes could pass an appraisal, they may, subject to their own judgments of relative quality and of other factors (a task outside the terms of reference of the Appraisals Committee), recommend where enrolment should be changed in accordance with the possibilities indicated in section 3 (c).

APPENDIX 2

Prepared by

Committee of Heads of Ontario

Electrical Engineering Departments

A REPORT ON DOCTORAL STUDIES IN ELECTRICAL ENGINEERING IN THE PROVINCE OF ONTARIO

April 25, 1973

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ABSTRACT

In this report the Electrical Engineering discipline group in Ontario, comprising the department head, chairman, or person responsible for studies in Electrical Engineering at each of eight universities, presents its collective views on the statements known as "five-year plans" submitted by the universities to the Advisory Committee on Academic Planning (ACAP), an arm of the Council of Ontario Universities (COU).

The essentials of the institutional statements are summarized and broad general comments are made on them. The discipline group was asked to report on "PhD activities and plans in the discipline group area, noting both apparent conflicts and gaps in both areas of specialization and enrolment". This we have attempted to do.

Proposed general goals are set forth for the group of Electrical Engineering departments (or equivalent). In the context of these goals, we find no reason to perturb the present system unduly. The record shows rapid development of doctoral studies in Electrical Engineering in Ontario in the last twenty years. At present there is a pause in the growth of enrolment, indeed a slight decline. We see signs that, while growth may be inhibited in the next year or two, both demand and need will lead, and should be allowed to lead, to modest increases in enrolment by the academic year 1977-78.

We believe that good doctoral work is proceeding at all eight universities, large and small, and we do not support the view put forward in the report "Ring of Iron" that doctoral work should be discontinued at some of these universities.

INTRODUCTION

This report has been prepared for consideration by the eight universities at present engaged in doctoral work in Electrical Engineering in Ontario. The universities so engaged are Carleton University, McMaster University, the University of Ottawa, Queen's University at Kingston, the University of Toronto, the University of Waterloo, the University of Western Ontario, and the University of Windsor. The department heads (or chairmen) of the Electrical Engineering departments (or equivalent) at these universities have met together at intervals since 1968 as the Committee of Heads of Ontario Electrical Engineering Departments. Responsibility for this report rests with the Committee. The report will be submitted to the universities and to the Advisory Committee on Academic Planning (ACAP), Ontario Council on Graduate Studies (OCGS), Council of Ontario Universities (COU).

The main basis for the report is the set of statements submitted by the eight universities to ACAP in January and February, 1973. These statements, commonly called "five-year plans", were intended to present, for each university, in accordance with the approved "Engineering PhD Planning and Assessment Procedures" of September 25, 1972, "current and proposed PhD activities including

(a) areas of research and study

(b) educational goals and style

(c) enrolment ranges

projected to five years ...". In preparing the report the committee has also had at hand summary data prepared by ACAP on the curricula vitarum submitted to it by the universities on their electrical engineering professorial staff.

In accordance with the same Procedures this report should cover "PhD activities and plans in (the) discipline group area, noting both apparent conflicts and gaps in both areas of specialization and enrolment." Also in accordance with the Procedures, this report will be subject to revision if, after considering it, there is any modification of the statements (five-year plans) by the universities.

It is expected that the final report will be made available, with the university statements and quantitative data, to the team of consultants when its work begins.

SUMMARY OF INSTITUTIONAL STATEMENTS

The university "five-year plans" have addressed themselves primarily to the specification of areas of research and study. For the most part the institutions project that they will continue work in the general areas in which they are now engaged. With an eye to the current constraints on university financing in general, on the support of engineering faculties in particular, and on graduate work, there are few proposals for the opening up of major new areas.

Perhaps implicit in the projection of a steady-state period for research activity is a belief that doctoral enrolments will not change greatly in the five-year period now in prospect. At least, for those institutions that have ventured to provide projected enrolment ranges (and not all have) there are no dramatic figures to indicate significant projected growth or significant projected decline. While most seem to expect little if any change, there is some tendency to hope for modest increases, particularly toward the end of the five-year period. Perhaps the rationale for this is that, despite current constraints (the major ones are listed below), there are several reasons for believing that doctoral enrolments will not decrease significantly and may indeed begin again to rise if unduly severe constraints are not imposed. There are indications that demand for PhD graduates, which has been reasonably good, is now increasing. From data gathered by the Council of Ontario Universities it seems clear that, of 122 persons graduated with the doctorate in Electrical Engineering in Ontario between September 1, 1968, and October 31, 1972, all but one were employed before January 1 of the year following graduation.

Some of the constraints that may have caused at least a short-term decline in enrolment include:

1. rather large fee increases for graduate students imposed, in effect, by the Government of Ontario,

2. reductions in the number of certain types of fellowships available to graduate students in engineering,

3. new restrictive criteria on eligibility for some fellowships,

4. restrictions on the support stipends that may be paid to full-time graduate students, both Canadian and foreign, for instructional services rendered.

These constraints, together with an overreaction by graduates from Bachelor's programmes to their concept of the marketplace (this concept having been generated partly by the press and partly by real oversupply situations in some other fields) may not only cause a decline in enrolment, but may cause it at a time when demand is beginning to increase.

The institutions have found it difficult to address themselves to matters relating to goals and style. Perhaps the goals are too complex to be defined. Perhaps style is either too difficult to define in words, or is implicit in the accounts given of research areas, or is too nebulous to be worthy of consideration. Goals for doctoral work in electrical engineering in Ontario may be less difficult to define than they are for a particular institution. A suggested definition of goals will be presented in this report. The universities may see fit to support the broad goals suggested.

Taken in alphabetical order the institutional statements (five-year plans) may be summarized as follows. The projected enrolments are maxima indicated for the end of the five-year period i.e., for 1977-78.

Carleton University

Major Areas:	Electronics Information Systems
Projected Enrolment:	18 full-time 22 part-time

McMaster University

Major Areas:	Communications Engineering Systems Engineering Materials and Devices
Projected Enrolment:	22 full-time

University of Ottawa

Major Areas:	Communications Systems Computer Engineering Control Systems
Projected Enrolment:	14 full-time

Queen's University

Major Areas:	Communications Electronics Energy Processing Systems
Projected Enrolment:	20 full-time 4 part-time

University of Toronto

Major Areas:	Communications Computers Control Power Devices and Systems Solid State and Electronics Wave Sciences Biomedical Electronics
Projected Enrolment:	61 full-time

University of Waterloo

Major Areas:	Computers and Communications Control, Systems and Networks Materials, Devices and Circuits Power Antenna and Electromagnetic Engineering Bioengineering Electroacoustics
Projected Enrolment:	None given

The University of Western Ontario

Major Areas:	Applied Electrostatics Radio Science
Projected Enrolment:	Estimate of 5 (Not explicitly stated)

University of Windsor

Major Areas:	Electric Power Systems and Signals
Projected Enrolment:	8 full-time 3 part-time

COMMENTARY ON THE PLANS

In the foregoing summary the specifications of major areas uses the terminology adopted by the institution itself. In most cases the institutional statement provides further definition either of subareas or of the scope of current and planned activity within a major area. The present and proposed scope of doctoral activities reflects the history of the development of doctoral work in Ontario in Electrical Engineering. It is a rather short history, covering little more than twenty years.

The overall picture has developed to a large extent from the interests and aspirations of academic staff and doctoral students. It has to some extent been influenced by the support for these interests and aspirations that has been obtainable from sources of research funds, and also by the availability of university academic operating funds. Research support is derived largely from federal government sources and to a very limited extent from industry. Academic operating funds are derived from both provincial and federal sources, though at present the federal component is channelled through the provincial government. Federal funding during the period under review has come primarily from the National Research Council in the form of Operating Grants. There has been very little attempt to influence the nature of the work attempted or its direction. Grants are awarded, subject to the availability of funds, on the basis of peer judgements. Work proceeds in an atmosphere that is, while competitive, free in an academic sense. Constraints relating to clearly perceived industrial or social relevance are only beginning to appear. The research contract or agreement, and forms of grants with strings attached, are only now beginning to play a larger role in determining the environment in which university research in engineering is pursued.

It should not be assumed however that the interests and aspirations of staff and students have been unrelated to the needs of the marketplace. The employment situation for doctoral graduates in electrical engineering has been good. The universities have reported no substantial difficulty with placement. The institutions believe, not unreasonably, that general unfavourable and often erroneous publicity in the past two years about employment problems for doctoral graduates may have caused some short-term decline in enrolment, and that the resultant shortage, combined with an upturn in the economic cycle will likely stimulate intake. It could even conceivably cause some of the recent inhibiting controls to be relaxed. Without such relaxation there may again be substantial exodus of able young engineers, especially to the United States, for the pursuit of graduate work.

The existing picture is as rational as it is partly because of the natural interplay of academic interests and economic factors. It is likely also that increased interinstitutional communication has been a factor. Interaction between the heads and chairmen of Ontario Electrical Engineering departments or their equivalents began in a more-or-less formal way in 1968. The members of this group have met at least twice a year since that time. Information has been exchanged in a limited way on activities and plans. There is no clear indication that this interaction has inhibited any university or its staff from pursuing doctoral work in such broad areas of interest as communications, computers, electronics, power and control. Whether the amount of duplication in some of these areas is excessive or not is debatable. Communications in one form or another appears as a major area for virtually every school. Yet there seems to be no employment problem in this area. Power appears, in one guise or another in only about half of the listings. This field is more heavily supported in Canada than in the U.S.A. Probably this reflects industrial needs. No employment problem has been experienced.

There are at present about 146 full-time Electrical Engineering doctoral candidates in the eight schools with about forty percent of these at the University of Toronto. We do not sense that this number is unduly large or that there is undue duplication. The eight schools serve a province which is central in both location and importance to the industrial life of the country. The schools are concentrated geographically close to the centres of heavy industry and secc dary industry, and to the main national as well as provincial centres of research in electrical and electronics engineering.

Are there significant areas of neglect or underemphasis? Again, and in the main, we believe not. But we have a bit of doubt. It is possible that, following a pattern in which existing fields of interest are pursued with great intensity and for a long period of time, perspective may be lost both by research workers and by those who pass judgement in determining whether the work should be supported. For this reason there may be undue concentration in some areas - which may be quite sound academically, but of questionable value in the context of national importance - to the near exclusion of others that are important and also significant in an academic sense. One might contemplate whether too much effort is going into study of the solid state, or into communications, or into control systems - and particularly into the more purely mathematical aspects of these subjects - when perhaps more effort is required on the problems of the environment, on the study of energy sources, on transportation problems, and on interdisciplinary activity. One may deplore in this context the pressures, particularly on younger staff members, to publish at as great a rate as possible to secure the continuance of research grant support at a relatively modest level, when the publications may be rather ephemeral or in the long view inconsequential, and when, with less pressure or pressure of a different kind, new problems might be attacked with results of greater significance and more lasting importance. Data made available to the committee in March, 1973, indicate that average personal operating research grants in the hands of university electrical engineering staff in Ontario in 1972-73 ranged, by institution and averaged over only those who held grants, from a minimum of $6,450 to a maximum of $14,052. These figures include only operating grants from the National Research Council, the Defence Research Board, and the Medical Research Council. Because funding for contract research is not included, as well as some other forms of government and industry support for research, there is reason to question whether these data give a true and adequate measure of total research support in Electrical Engineering. The measure used would perhaps be more appropriate for science departments than for engineering departments.

In spite of any doubts we may have about the direction of current research, we see little point in attempting to constrain the university system unduly to bring about change. The central purpose of the universities is to educate, not to solve national problems or even major industrial problems. There seems little likelihood at present that any university or group of universities will be funded so liberally that major, planned research impact will be achieved. One might expect such impact, under current systems of financing, from government or industrial research organizations, such as the Communications Research Centre, Bell Northern Research, the research laboratories of the major power utilities, and perhaps other industrial research laboratories (though the number of these is small). Even this assumption may be questionable because of the tendency to concentrate on development and on relatively short-range problems.

Instead of constraining the universities with respect to areas of research it may be more fruitful to depend upon their interaction and upon the form of control exerted by major granting and contracting agencies that are, or should be, responsive to national goals.

In spite of all that has been said in the preceding paragraphs it must be conceded that by chance or good fortune or through sheer competence a particular department or professor or doctoral candidate may have more impact on an important and real problem than any planned attack involving government, industry, universities or coordinated effort by one or more of these constituencies. When at a particular time this happens it should be regarded as a happy byproduct of what is basically an educative process. Nevertheless, to enhance the prospects for truly relevant and useful research it is desirable to seek more effective means for promoting liaison - to the point of mutual involvement in some cases - between university electrical engineering departments and the research arms of government departments and industrial corporations.

We do not see the existing pattern in Ontario as being excessively duplicative, nor do we see it as a matter of great urgency to attempt to drive any of the departments in new directions, different from those in which they are now proceeding. As we have said, the history of doctoral work in Electrical Engineering in Ontario is relatively short. As we proceed and mature in this environment, and particularly as young staff mature in it we can hope for a more seasoned approach to the problems of rationalization and relevance. Twenty years ago there was virtually no doctoral work. Senior staff in established departments saw for their departments a purely teaching role, or a teaching and consulting role. Many other departments and engineering faculties in the province were in a nascent state. All this has changed. The evolved system has also become expensive. It is reasonable however to count the cost as an investment - one that should be protected from anything in the nature of arbitrary, short-sighted, suddenly imposed, and irrational constraints. In their evolutionary period the departments of Electrical Engineering have demonstrated their flexibility. There are good grounds for assuming that this flexibility will continue and will permit readjustment to meet the changing needs of the province.

GOALS

Earlier in this report it was indicated that few of the university statements had addressed the matter of goals and style. It would probably be presumptuous here to say anything about the collective "style" of the group of eight, except perhaps to say that each department or equivalent cherishes its independence. On the subject of common goals it is a little easier to be forthright and to attempt definition.

We believe that the pursuit of doctoral work in Electrical Engineering in Ontario should proceed with the following broad and general goals.

1. Contribution of new knowledge to electrical and electronic engineering and allied fields.

2. Maintenance and improvement of academic standards such that students of Electrical Engineering from Ontario and from the rest of Canada can expect to find opportunity to develop their intellectual capacities to the highest level without necessarily having to leave the country.

3. Graduation of students who will meet not only the demands of industry, government and universities for doctoral staff, but also the needs, sometimes perhaps unseen, of the province and the country for creative entrepreneurial skill of the highest order.

We see these goals being met by maintenance of the existing system, which is relatively new. We see no point in expanding it, but we also see no point in winding it down when it has scarcely had opportunity to mature.

ENROLMENT PROJECTIONS

This committee supports the position that good doctoral work can proceed in small departments and in large ones. In small ones, good work at the doctoral level can proceed even if only a few staff members are involved - provided they are competent, believe in what they are doing, can attract students, and are subject to a university-imposed regulative process that insures the maintenance of minimum standards through the use of comprehensive examinations, external thesis examiners, and the like. There appears to be no need to defend the viability of doctoral work in the larger departments. We agree with this in particular in Ontario because we know the schools. Large size in itself of course may not be a guarantee of work worthy of recognition.

It follows that we do not support the position taken in the report "Ring of Iron" that doctoral work at any of the eight institutions now pursuing it should be stopped. This does not remove the difficulty of making rational judgements about what enrolment projections should be recommended by this committee.

What has been acceptable to the whole committee is to put forward, as listed below in Table I, the maximum enrolment of full-time students that each department head, chairman, or equivalent considers acceptable as a reasonable level of doctoral activity in Electrical Engineering in his institution for the five-year period in prospect. For the system as a whole the committee believes that the total suggested full-time enrolment is reasonable. To support this view Table I included listings of the full-time PhD enrolment in 1970-71, a year in which this enrolment reached its peak, and for the current year. We expect that market forces, if there is not undue regulatory interference with them will lead to increasing PhD enrolment in the next few years.

TABLE I

University	Full-Time PhD Candidates		
	1970-71	1972-73	1977-78
Carleton	16	12	18
McMaster	15	16	22
Ottawa	7	10	14
Queen's	14	15	20
Toronto	59	61	61
Waterloo	44	24	37
Western	3	2	5
Windsor	11	6	8
Totals	169	146	185

Further consideration of enrolment projections, for either full-time or part-time enrolment or both, should take into account the need for graduates with the PhD (which we believe is likely to increase), the need to utilize as fully as possible the existing staff and plant, and the need to maintain a certain justifiable geographic dispersion of effort over the populous portion of the province.

If enrolment ceilings are established we recommend that they be reviewed within two years by the discipline group to permit readjustment if this proves for any reason to be desirable. In making this recommendation the committee assumes that the current system of formula financing will be continued. Should this not be so we would be concerned only insofar as any change, for example a reduction in the formula funding for doctoral candidates, might affect the general welfare of engineering education at all levels. There would be cause for real concern if steps were taken to squeeze the funding of engineering faculties more than is currently the case.

APPENDIX 3

ASSESSMENT OF INDIVIDUAL UNIVERSITIES

General

The assessment of the individual universities follows where possible the requirements contained in the "terms of reference of consultants" which require a "report on the adequacy of the present state of doctoral work in electrical engineering in each university where applicable discussing

a. coverage of fields and specialties, and extent of activity in each

b. faculty quality and quantity

c. nature of programmes offered

d. enrolment size and distribution

e. quality of student body; admissions requirements

f. relationship to related disciplines and to the profession

g. physical facilities

h. other matters considered to be significant."

These assessments are based on visits by the consultants to the individual universities where interviews were held with the chairman of the department, representative members of the faculty, the deans of graduate studies and engineering and with approximately 6-10 graduate students or recent graduates. At the same time the research laboratories, computer facilities and library facilities were inspected. The data supplied by the individual universities on faculty, students, grants and programme also significantly influenced the assessment.

CARLETON UNIVERSITY

a. Coverage of fields and specialties

The development of graduate studies at Carleton University in electrical engineering has been relatively recent. Having no previous traditional barriers the graduate work in electrical engineering has been divided into two departments - Electronics and Materials Engineering and Systems Engineering. Together these constitute the total activity related to electrical engineering.

Activities in Electronics and Materials Engineering include solid state device electronics, circuits and circuit theory, microwave electronics, electromagnetic and optics and electron beam systems and processes. The Systems Engineering programme concentrates on areas of information systems such as communications and signal processing, decision and control, digital systems design and software engineering (planning, analysis, specification, implementation).

The coverage within these two areas appears well integrated and coordinated and appropriate for PhD training. Significant interactions with local government laboratories and industries have given the programmes a contemporary relevance rarely found in graduate programmes.

b. Faculty

The faculty consists of 21 full time members - 8 in Electronics, 2 in Materials and 11 in Systems Engineering. Only 2 of the 21 do not have the PhD degree. Sixteen of the faculty received their Bachelor degrees in Canada (7 in Ontario, 9 in the rest of Canada) - a significant number in Engineering Physics. The faculty includes 4 full professors, 14 associate professors and 3 assistant professors. The majority of the staff are in the 30-39 age bracket.

The overall impression of the faculty is moderately young, competent and dynamic. Extremely good leadership appears to be present in the groups.

Two of the four full professors active in graduate research received NRC/DRB grants (average value $17,000), while 8 of the 14 associate professors and all 3 of the assistant professors received similar grants (average values of $7,800 and $3,900 respectively). This represents only a partial picture of the research support since many of the faculty are involved in major projects funded by other sources such as, for example, the wired city (Department of Communications).

c. Nature of PhD Programme

A PhD programme is offered both in Solid State Electronics and in Systems Engineering. The degree requirements follow the traditional ones of courses, qualifying examinations and major thesis.

A significant difference in the programme at Carleton University is the large number of part-time PhD candidates. This is due to the presence of major government and industrial laboratories and is made possible by the strong relationships built up by the faculty and the external organizations. The number of part-time candidates often exceeds the number of full-time PhD students and comprises half or more of all the part-time PhD candidates in electrical engineering in the province of Ontario.

The formal graduate school application evaluation procedure appears very well administered.

The courses offered in the two areas of specialization are adequate and modern in scope. Some problems can arise in the range of courses offered particularly when candidates proceed to the PhD from a master's degree from Carleton. (The University policy is to have any candidate receive no more than 2 degrees from Carleton and this policy seems to be observed except for special circumstances.) Arrangements have been formalized with the University of Ottawa to give credit for certain courses presented at either university. Although the staff emphasized this relationship the students did not utilize the arrangement very extensively. The students indicated excellent accessibility and good working relationships with the faculty.

Overall, the nature, standards and administration of the PhD programme are good.

d. <u>Enrolment Size and Distribution</u>

The enrolments in the two major areas are given in Table C-1. Only slight increases in the PhD enrolment are anticipated over the next 5 years. Such an increase appears to be within the competence and capacity of the present staff.

A significant part of the total enrolment is comprised of part-time students who do part of their requirements in the local government and industrial laboratories. External assistance in joint supervision of the research work is also available thereby requiring no additions to the staff to handle a moderate increase in external part-time students.

TABLE C-1

Area	No. of Staff	1972/73 MSc FT	Candidate PT	1972/73 PhD FT	Candidate PT	1977/78 MSc FT	Candidate PT	1977/78 PhD FT	Candidate PT
Electronics and Materials*	10	21	9	6	6	20	10	8-9	8
Systems	11	20	34	7	14	20	42	9	14
	21	41	43	13	20	40	52	17-18	22

* No PhD programme is planned for materials.

It is considered that the part-time student programme, if it continues to be well administered, is a valuable part of the service to the local community and represents a contemporary role for the university.

e. Student Body and Admissions

The major attraction expressed by students gaining admission to Carleton University to do graduate research in electrical engineering is the idea of working closely with industry and government on topics of relevance. A direct benefit of this interaction is that most graduates have been able to make arrangements with a local government or industrial laboratory for permanent employment before actually completing their degrees. This is likely to remain a significant reason to prospective graduate students.

About one-third of the graduate students in electrical engineering come to Carleton with major scholarships. The majority (~50%) are, however, supported on research grants and demonstratorships. Canadians normally comprise about half of the full-time PhD student population and form the majority of part-time PhD candidates.

In summary the calibre of students appears good and Carleton is likely to be able to continue attracting students of this quality.

The admissions to the PhD programme usually require a master's degree with at least a high second class standing from a recognized university. In addition, a comprehensive examination must be passed by the candidate.

f. Relationship to Related Discipline and the Profession

The electrical engineering graduate programme at Carleton University has a very strong association with local government laboratories and industries. Amongst the groups involved are: the Department of Communications, the Communications Research Centre, the Department of Energy, Mines and Resources, the Department of National Health and Welfare, the National Research Council, the Canadian Post Office, Bell-Northern, Micro-systems International, the Ottawa Civic Hospital and the Canadian Nurses' Association. Within the University the two groups interact with each other as well as with the Physics Department, the School of Journalism, the Department of Linguistics and the Department of Psychology. Some cooperation with the Universities of Toronto and Ottawa and the Micro-wave Institute (Stockholm) also takes place. The above all relate to the graduate research programme. In addition, graduate classes are open to members of the local community and are normally scheduled in late afternoon to facilitate attendance by part-time students or others holding full-time jobs.

The interchange of course credits between classes taken at Carleton University and the University of Ottawa has been arranged but does not appear to be used very extensively.

It is considered that the Carleton University groups comprising the activity in electrical engineering are a model of the type of interaction which can be achieved between a university group and the local related governmental and industrial activities.

g. Physical Facilities

The research facilities include a modern solid state facility for the fabrication of microcircuits, laboratories equipped for research on micro-wave electronics, lasers and electron beam welding, a wired city simulation laboratory, on-line computers, anechoic chamber and linguistics laboratory. Adequate computer power and library exist within the university. The laboratory and office space is modern and appears well organized.

In addition, external facilities at the Communications Research Centre, Micro-systems International Limited and Bell-Northern Research Laboratories are available for joint projects.

Summary

The two departments at Carleton University have strong programmes in their own areas of electrical engineering. The interaction with local institutions is very pronounced and has had a significant desirable effect on the nature and relevance of the graduate programme. The groups should be encouraged to maintain this type of involvement. The PhD degree offered appears of a good standard and is likely to continue to attract suitable candidates in future. The part-time PhD candidate is likely to continue to be of major significance to the programme at Carleton.

MCMASTER UNIVERSITY

a. Coverage of fields and specialties

McMaster University has strength in three areas of graduate research and teaching, and has plans for strengthening one additional area. These are:

Communications and Data Processing: Research is being conducted on digital filters (including hardware implementation), high rate digital data structures, and simulation of a satellite communications channel, scheduling algorithms, micro-wave integrated circuits, self-synchronizing digital modulation systems, spectral analysis hardware.

Modelling and Design: This area is ordinarily known as computer-aided design. Work is being carried out on sensitivity evaluation, computer-aided design of micro-wave and analog filters, approximation, optimal control, and related subjects.

Materials and Devices: This work concentrates on semiconductor electric and magnetic devices at both low and high power levels. Some specific projects are ion implantation, radiation damage of thin-film devices, bubble memories, optoelectronic tuning, and design of high-speed linear motors.

Medical Electronics: Work is in progress on a communication aid for the handicapped. It is in this general area of medical electronics that the area is expected to develop.

Of the four areas, the number of the faculty in communications and data processing is 4.5, with 3.5 in modelling and design, 5 in materials and devices, and only one faculty member at present in the last. All of the areas appear to be adequately covered; outstanding work is being carried out in the first three.

b. Faculty

The faculty at McMaster prides itself on the high percentage of the faculty involved in research, with grants, and with good publication records. There is also a high percentage of the faculty with extensive industrial experience, and a reasonable level of current interaction with local industry. At the time of the completion of the forms in 1972, the Department had 11 NRC grants, 3 computation grants, and 5 others; more have been obtained since that time. Each of the three major areas covered by the Department have "stars" with international reputations. Three of the faculty produce journal publications at a high rate with over 30 on record since 1968. Interests of the faculty divide as shown in Table M-1.

TABLE M-1

(McMaster University)

Area	Number of Faculty	Master's Candidates FT	Master's Candidates PT	PhD Candidates (1971-2) FT	PhD Candidates (1971-2) PT
Communications and Computers	4.5			9	
Modelling and Design	3.5	21	3	4	3
Materials/Devices	5			4	
Medical Electronics	0.5			1	
TOTALS	13.5	21	3	18	3

It should be noted that this faculty total in Table M-1 does not match other tables since many of the faculty are shared and have only part of their total time allocated to electrical engineering. This is particularly true in the materials and devices area.

In relative standing with other universities in Ontario, the "Ring of Iron" may be cited (page 26, Table 5-2) to show that in (a) research support per faculty member, and (b) research publication per faculty member, for the period of the study, McMaster was significantly ahead of all others.

c. Nature of the PhD Programme

At McMaster, the requirements for the PhD degree are well organized and well understood. The decision as to whether a candidate is admitted to the programme is made after the completion of the master's degree, and is based, as is normal, on academic standing and promise in research. After admission, the student is required to complete four half courses, two of which must be outside his field of specialization. Later, he must take a comprehensive examination based on his general knowledge, both undergraduate and graduate levels. After completion of the doctoral research and the writing of the thesis, there is a defence of the thesis with an outside or external examiner. The list of external examiners was impressive, and there seems to be little if anything that requires improvement in the administration of the programme.

Several additional comments should be made concerning the programme and the students in i

(1) There is some interaction with local industry, and also there is some cooperation with the University of Toronto in courses in some areas (medical electronics especially) and in seminars.

(2) The Department has a dynamic seminar programme, and regularly invites outstanding speakers to come to Hamilton. Going in the other direction, the faculty are well travelled in attending conferences (both in the U.S. and Europe, as well as in Canada) and in presenting seminars themselves.

(3) There are not as many Canadian students in the programme as the faculty would like. However, in this connection, McMaster is not in a worse position than other Ontario universities except for the University of Toronto.

(4) There is no question that the present faculty could supervise a larger number of PhD students. However, the aspirations of the Department appear to be for only a modest increase in the present number of 18.

d. Enrolment Size and Distribution

The engineering departments at McMaster have made a genuine effort to satisfy the quota set for them by the Committee of Ontario Deans of Engineering. This has been difficult, of course, with the usual uncertainties of time of completion and time of admission; at the time of the visit it was met exactly.

The proper distribution of the 18 PhD candidates is determined mostly by the interests of the students and the degree to which the area is established. The Communications Research Laboratory is well established and doing significant research, and so it is not surprising that most of the students are in that programme. The research in Materials and Devices is similarly well established, and the laboratory facilities are indeed outstanding. However, it is almost universal that it is difficult to induce students to enter this area.

e. Student Body and Admissions

It has already been noted that a larger number of the students in the programme enter from outside Canada than the faculty would desire. However, good students do enter the programme from Canada, from both McMaster and other Canadian universities.

Admission standards are clearly stated and well administered, and there seems no reason to question the high quality of the students in the PhD programme.

f. Relationship to Related Disciplines and to the Profession

The area with the most obvious interdisciplinary aspects is that in Materials and Devices. Not only are many of the faculty shared with other departments, but all of the faculty from Electrical Engineering and other departments with an interest in materials make use of the facilities of the Institute for Materials Research.

These facilities are comparable to the best in any universities in North America, and the administrative policy of assigning primary responsibility makes the total facility operate smoothly.

The Communications Research Laboratory does not relate so obviously to other departments in the University, but it is closely connected through its financial arrangement with both governmental and industrial laboratories.

The Modelling and Design area has grants from industry to develop specific computer programmes or to make specific recommendations of a commercial nature. The Medical Electronics programme, although a very small one at this time, is clearly one with high potential for interdisciplinary interest and cooperation. The Department's interest in bioengineering does not appear to be related to the established facilities in the medical centre of McMaster University.

The Department conducts cooperative research with such industries as RCA, Westinghouse Canada, Canadian General Electric, Bell-Northern Research, Canadian Atomic Energy, etc. It should not be inferred that the cooperation with the industrial sector in Hamilton compares in any way to the level attained in, say, Ottawa. Given the nature of industry in the Hamilton area, the Department does very well indeed, and seems to have real concern for improving this cooperation when possible.

g. Physical Facilities

There is now adequate space for the research programmes of the Department. If there is a problem, or an area needing some improvement, it is that the space is spread out over several buildings. This in turn causes some loss in contact of faculty members with each other. The situation is by no means serious.

Summary

The programme in electrical engineering at McMaster University is of high quality, with a productive and dynamic faculty, and a good student body. Moreover, this trend for improvement in quality does not give any appearance of stopping. Hence we are presented with the problem of quality programme with a small enrolment quota.

There is good reason to question the wisdom in encouraging the development of a larger programme in Medical Electronics unless it can be done in close collaboration with the Medical Centre. A very good laboratory in this area exists at the University of Toronto, with a wide and diversified span of interests on the part of its faculty, including medical electronics. In addition, the need for graduates in medical electronics has been developing very slowly in Canada and in the U.S. This need may increase in the future, but it is very modest at present.

UNIVERSITY OF OTTAWA

a. Coverage of fields and specialities

Graduate work in the Electrical Engineering Department at the University of Ottawa is concentrated in three areas:

Communication Systems: including error-correcting codes, source encoding and arithmetic codes, analog and digital filter realization and optimization, signal design, and the general field of micro-wave communications.

Control and Systems: including modern control theory, distributed parameter systems, hereditary and societal system theory, and power systems.

Computer Engineering: including computer design (organization and architecture aspects), applications-oriented structures, switching and automata theory, and digital electronics.

It must also be recognized that until recently a fourth area was included, namely solid state electronics (integrated circuits, circuit fabrication, design, etc.). This area has now been de-emphasized due to the illness and leave of absence of Professor G. S. Glinski. However, some equipment and generous amounts of space still remain should an interest in this area revive.

With a graduate faculty of 11, it is clear that the faculty are spread thinly among this number of sub-areas. It is noted that the extension of systems concepts to hereditary and societal systems is exploratory only, and that course work in modern power systems and research in power devices was initiated in 1972 with the appointment of one new faculty member.

b. Faculty

Of the faculty of 14, 11 participate in research and graduate-level teaching. Fifty percent of the faculty have the PhD degree, and only 2 are of Canadian origin. The relatively recent growth of the Department has resulted in a distribution with 2 full professors, 6 associate and 6 assistant professors. Some of the characteristics of the faculty, excluding the 3 who do not participate in the graduate programme, are shown in Table O-1.

The faculty have 7 NRC grants at an average level $6,100, 3 other grants, 1 University grant, and 1 NRC grant for computing.

The two best known members of the faculty are in the communication and computer fields, and they enjoy international reputations. A number of other faculty members appear promising. Even so, the number of faculty with a genuine involvement and dedication to graduate-level education is smaller than it should be for a PhD degree-granting institution.

TABLE 0-1

(University of Ottawa)

Area	Number of Faculty	1972-73* Master's Candidates FT	PT	1972-73* PhD Candidates FT	PT
Communication Systems	2	4	4	1.5	1
Control and Systems	4	2	2	1	0
Computer Engineering	3	1	1	6.5	2
Electronics (Digital Electronics)	2	4	0	1.0	1
TOTALS	11	11	7	10	4

* Figures as of the fall of 1972. It does not include students of Steenaart or Schenk.

c. Nature of the PhD programme

The requirements for the PhD degree are those traditional in the field: 16 course credits beyond the master's degree, a specified number of credits for research, oral or written examinations, a thesis, and a satisfactory defence of the thesis. One aspect of the administration of the PhD programme at the University of Ottawa that is unusual is a casualness made possible by the small size of the student body involved. Admission to the PhD programme normally comes only from those who have completed the master's degree and so are known to have "high course average and demonstrated research ability". Also, the oral or written examination is never administered, according to the students.

Three aspects of the programme deserve mention:

(1) The graduate courses are offered in the late afternoon and evening so that they are available to students from Ottawa industry as well as the students in the Department. The number of courses offered ranges from 10 to 15. Not all of these are actually offered due to small enrolments, but those that are offered sometimes attract as many as 25 students. Some of the courses are given by lecturers from industry.

(2) An outstanding seminar series was sponsored during 1972-73 attracting many speakers with international reputations in a variety of fields; indeed, the series is as attractive as any offered by a university in North America.

(3) Some students are encouraged to work in Ottawa industry on some aspects of their thesis research, if industry has unusual equipment or expertise. Such cooperation with industry needs further encouragement.

(4) For the oral defence of the thesis, an external examiner is included for thesis evaluation. The list of external examiners used in the past is impressive.

(5) Some observations on the programme follow:

  (a) The student body seems somewhat below critical size for proper interaction between students.

  (b) A relatively high percentage of the students working for the PhD are of foreign origin.

  (c) The level of research support in the Department is low.

  (d) Many of the theses are totally theoretical in nature.

  (e) There is a lack of equipment in the Department, and that available did not appear to be in use.

d. Enrolment Size and Distribution

The Department at the University of Ottawa has felt constrained to satisfy the quota system set up by the Committee of Ontario Deans of Engineering, and, with effort, have held enrolment to 10 full-time PhD students. Without this constraint, the number would be larger. The Department believes that it is capable of supervising up to 14 full-time PhD students.

e. Student Body and Admissions

Like many departments of its size and recent entry into the competition for PhD students, the University of Ottawa attracts most of its students from two sources: (1) its own students or those residing in the area for purposes of employment; (2) students from abroad. Most of the non-Canadian students now come from Taiwan, Egypt, and India. The local students who elect to remain at the University of Ottawa are of high quality.

f. Relationship to Related Disciplines and to the Profession

For the areas in which it specializes, there is limited opportunity to interact with related disciplines within the University. There is close collaboration between the programme in computer engineering and faculty members in the Department of Computer Sciences. There is some collaboration due to common interests of the communication systems faculty with those at Queen's University in Kingston.

It appears that interaction with Ottawa industry is now beginning to grow. While there has been interaction in the past, Professor Steenaart has initiated an experimental communications laboratory and will offer some of his courses jointly with staff members of local laboratories, often at their facilities. It is unfortunate that there is not more interaction with the electrical engineering faculty at Carleton University. While there are intersections in the interests of the faculty in computer engineering and in some aspects of communication, there seems to be minimal contact by the faculty, and a few of the students at either university attend either courses or seminars at the other. Evidently, the machinery is set up to make such exchanges simple and routine for the students, and perhaps needs stimulation.

g. Physical Facilities

Colonel By Hall is a modern and comfortable building, for which there will be full occupancy by 1980. The Department occupies several floors of this Hall. There appears to be adequate space available in total, with some parts not used at the present time, due primarily to the abandonment of plans for a solid-state laboratory. Thesis work at the PhD level is almost entirely theoretical, except for the usual digital calculation or simulation, and so additional experimental facilities do not seem to be needed. Computer and library facilities seem adequate for the programme of research in progress.

Summary

The University of Ottawa plays a unique role in Ontario as a bilingual and bicultural university. This appears to be especially important at the undergraduate level. There at least some of the courses are offered in French, and there is an opportunity for students of Francophone origin to associate with each other. At the graduate level, all courses are offered in English and the student body is more cosmopolitan with a distinct minority having French-speaking origins. Thus the need for a bilingual university does not appear to be as pertinent to the technical aspects of the PhD programme.

A department with a small faculty and a small number of graduate students can operate an effective PhD programme only with a competent faculty, strength and breadth in complementary fields, and an adequate research environment. While the University of Ottawa has some outstanding faculty members, it does not appear to have attained an interacting and reinforcing research atmosphere.

Further, it has not been able to attract consistently outstanding students. The programme appears to lack both focus and tight administrative policy. These are difficult problems. However there is a sincere effort being made by the present chairman of the Department to rectify this situation. There are some indications of improvement.

QUEEN'S UNIVERSITY

a. Coverage of Fields and Specialties

The Department of Electrical Engineering at Queen's University offers graduate training in four principal fields:

Communications: the research in this field covers optical signal processing, radar signals, digital communications, source and channel encoding, waveguide structure, and the application of communications technology to transportation systems and to radio astronomy.

Electronics: includes work on micro-wave semiconductor devices, in instrumentation for communication systems and for bioengineering systems, and on the application of digital computers to the study of physical phenomena.

Energy Processing: covers research in electrical machines, power system stability and system modelling, solid-state electric drives and propulsion systems for ground transportation.

Systems: research is directed towards the analysis and design of digital control systems, hybrid computer simulation in control analysis and design, and systems identification.

b. Faculty

The faculty consists of 3 full professors, 6 associate professors, 8 assistant professors and one visiting lecturer. Eleven of these have the PhD degree, and the rest have master's degrees. The majority of the staff are in the 30-39 age group. Two-thirds of the faculty are Canadian by birth and half have one or more degrees from Queen's University. One of the full professors holds a major operating grant ($34,820), 3 of 6 associate professors hold grants (average value $9,567), and 7 of 8 assistant professors hold grants (average value $5,564).

Each research field comprises 4 to 5 members. The communications group is without question the most active and best-funded (communications-related projects have attracted more than 80% of the research funding available in the Department, which for 1972-3 was in excess of $220,000). The systems group interacts to some extent with the communications group and achieves modest research support (approximately $30,000). The direct support for research in energy conversion is small, as is that for electronics.

c. Nature of the PhD programme

The PhD degree is awarded on the completion of a programme of course work and research. The courses required entail a minimum of 14 term-hours beyond the master's degree (which itself requires 14 term-hours of courses, of which 9 must be at the graduate level within the Department).

It is normally expected that the thesis research will make up at least two-thirds of the time required for the programme, and it is stated in the Calendar that it "must be original and should further existing knowledge of the subject". The formal requirements for supervision of the research of the doctoral candidate appear to be adequate.

The department offers an adequate range of graduate courses, with some degree of specialization in those fields in which the doctorate is offered. There is adequate support from the Departments of Mathematics, Physics, and Computing and Information Science. There does not appear to be required participation in regular seminars (by graduate students).

The examination requirements include a language examination, a comprehensive examination (written and oral) and a thesis oral examination. An assessment by an external examiner is required for the thesis examination.

d. Enrolment Size and Distribution

The present doctoral students number 17, 15 full-time and 2 part-time. From the data available, the distribution of those students among the four fields appears to be Communications - 8, Electronics - 1, Energy-Processing - 1, and Systems - 7, but the degree of overlap of group interests makes this assessment difficult. There is some correspondence between group strengths as shown by funding and student acceptance.

Insofar as future plans are concerned, the University has stated that the projected full-time enrolment in 1977-78 is anticipated to be 20, with 4 part-time.

e. Student Body and Admissions

Queen's University has had average success in attracting the better graduate students. Approximately one-quarter of the graduate students in Electrical Engineering have held major scholarships at any one time over the past five years.

Although Canadians constitute a majority among master's students at Queen's, it is noticeable that they form a definite minority among doctoral students (less than 20% in 1972-3).

The minimum requirements for admission to the doctoral programme are a master's degree or, alternatively, the admission qualifications for the master's programme (2nd-class standing as a minimum) plus one academic year of satisfactory full-time graduate study at a recognized university. It is the opinion of the consultants that the Department should raise its sights well above the minimum.

Candidates are permitted to take all of their degrees from the baccalaureate through the doctorate at Queen's University.

f. Relationship to Related Disciplines and the Profession

The University does not have the advantage of being ideally located with respect to industry or to government laboratories as some others do. Evidence of this isolation was apparent. However, some sectors of the Department have made efforts in the past few years to interact with other groups on the campus, in government laboratories, and in industry. This has obviously had a stimulating effect on the Department's productivity and research relevance. Further efforts in this direction would be of significant benefit to the Department.

Within the University, a major project currently underway is an interdisciplinary project sponsored by the federal Department of Communications, in which the Department of Electrical Engineering is cooperating with the Departments of Psychology, Sociology, and Political Studies, and with the School of Business in studying the sociological and psychological impact of communications technology.

A major mechanism for cross-fertilization between fields and between the Department and industry is the Canadian Institute of Guided Ground Transport, in which members of the Department are very active.

g. Physical Facilities

The departmental facilities are well-suited to undergraduate instruction but seem inadequate for graduate and faculty research on any scale. It is noticeable that there is a lack of major experimental apparatus; the departmental equipment lists are not impressive.

Summary

The Department shows good strength in Communications and fair strength in Systems as major fields of concerntration. At the doctoral level, it is doubtful that it should offer programmes in Energy Processing or in Electronics as a separate field from Communications at its present state of development.

There appears to be a high rate of disappearance of Canadian students between the master's and doctoral stages; the Department should take steps to correct this situation.

UNIVERSITY OF TORONTO

a. Coverage of fields and specialties

The Department of Electrical Engineering at the University of Toronto covers the following seven areas:

Communications - which includes data collection and switching, distributed switching systems, data transmission and distributed computing systems. This is the newest and one of the smallest of the groupings within the department.

Computers - including circuit theory and design, logic design, computer organization and architecture, switching and automata theory, high speed data acquisition systems and medical and pollution monitoring instrumentation.

Control - covers process control, large scale multivariable systems, computational techniques, linear systems theory, systems identification and distributed parameter systems. The group is highly theoretically oriented.

Power Devices and Systems - includes electric machinery (linear induction and synchronous motors) power systems analysis and control, solid state electronics applied to power and quasistatic electromagnetic field applications. The group is moving towards greater involvement in areas related to transportation.

Solid State Electronics - covers MOS and MNOS devices, charge-coupled devices, optical arrays, special transistors, "bucket-brigade" circuits and thick and thin film microcircuit fabrication.

Wave Sciences - includes projects in antennas, plasmas, masers, Josephson junction devices, microwave and optical holography, microsonics and radio astronomy.

Biomedical Electronics - a number of members of the Electrical Engineering Department are members of the Institute of Biomedical Electronics and Engineering. The activities are directed to development of instrumentation for various medical applications. The Institute is unique in Canada and attracts far more applicants than it is able to accept.

The scope of the fields covered within each of the areas is eminently adequate for a PhD programme in electrical engineering.

b. Faculty

The faculty consists of 42 full-time members and 2 part-time staff. All but 9 of these have the PhD degree. Of the order of 60% of the staff is of Canadian origin. The number includes 15 Professors, 21 Associate Professors and 6 Assistant Professors. Six of the faculty hold cross-appointments with other departments. Excluding the faculty with cross-appointments and part-time staff, 7 of the 12 full professors have major grants (average value $20,500), 16 of the 18 associate professors have major grants (average $13,300) and 4 of 6 of the assistant professors have grants (average value $5,800). The majority of the staff are in the 30-49 age bracket so that few positions will become vacant due to retirements.

The distribution of the faculty by field is given in Table T-1. (Since some members have interests in several fields, most fields therefore do not represent whole numbers of faculty.) The groups are of the order of 6 faculty members. An inspection of the publications and research activities of the faculty within the last 5 years indicates a large number of "stars" within the department. (A star is defined as a person with an outstanding publication record, an international reputation in his specialty and the ability to directly attract graduate students who come to work with him rather than to the university for any other reason.) The "stars" are well distributed over the different groups indicating a significant breadth in outstanding faculty members over the department. Some of the younger members of faculty appear to have "star" potential.

c. Nature of PhD Programme

The PhD programme in Electrical Engineering at the University of Toronto can be described as traditional.

The programme consists of course requirement of 6 one-term courses beyond a master's degree (the MSc requirements are 6 one-term courses plus a thesis) together with a major research thesis which "constitutes a significant contribution to knowledge in the field".

The courses offered range widely and constitute most of the advanced modern topics in electrical engineering. In addition, courses from other departments can be taken for credit where appropriate. The student thus has probably the best selection of courses to choose from of any university in Ontario.

The thesis research topics are selected in any of the seven major areas of interest in the department and supervised by a faculty member. In addition, cross-departmental topics are possible where the candidate works under joint supervision by members from several departments.

Research seminars involving the students are part of the programme but tend to be attended along areas of research interest making the total department operate in part as 7 mini-departments.

Examination requirements include a qualifying examination and an oral defence of the thesis. An external examiner is included in the thesis evaluation. Students have expressed some dissatisfaction regarding the clarity of departmental policies, particularly regarding examinations and are not satisfied that these are uniformly administered.

A time limit of 7 years is imposed on the duration a candidate can be enrolled in the PhD programme. Overall, possibly due to its size, the administration of the programme tends to be somewhat impersonal.

d. Enrolment Size and Distribution

The enrolments in the various areas are shown in Table T-1. It is expected that the total PhD enrolment will remain constant in the range 60-65 over the next 5 years although shifts in emphasis are likely to occur. The department considers itself to be at a mature and optimum level.

TABLE T-1

Area	Number of Staff	1972/73 MSc Candidates		1972/73 PhD Candidates	
		FT	PT	FT	PT
Communications	4.20	11	4	4	0
Computers	5.63	23	6	13	0
Control	6.57	12	2	9	1
Power Device & Systems	9.10	21	12	11	2
Solid State Electronics	3.70	11	2	6	0
Wave Sciences	6.40	9	1	5	0
Biomedical Electronics	6.40	10	6	13	0
	42.00	97	33	61	3

(1977/78 enrolments expected to be approximately the same as in 1972/73)

e. Student Body and Admissions

The University of Toronto has been able to attract graduate students of outstanding ability. Of the total MSc and PhD student population more than half hold major scholarships, about a third of the total being NRC scholars. Of all NRC scholars in Electrical Engineering attending Ontario universities, about 2/3 chose the University of Toronto.

Much greater emphasis is placed at Toronto on students gaining their own financial support. For outstanding applicants, the School of Graduate Studies awards University of Toronto Fellowships. (The number of such awards has ranged from 6 to 14 annually.) Only about 25% of the graduate students rely totally on demonstratorships and research grants for their financial support.

About 60% of the graduate students in Electrical Engineering are Canadians - a much higher proportion than in most of the other Ontario universities.

Admission to the PhD programme requires at least a 4-year University of Toronto degree with at least B standing or its equivalent. Continuation in the programme requires maintenance of this standard and demonstration of research ability. In addition the candidate must pass a qualifying examination. Candidates are permitted to take all of their degrees (Bachelor's, Master's, Doctorate) at the University of Toronto.

f. Relationship to Related Disciplines and to the Profession

The Electrical Engineering Department interacts to a significant degree in related fields and with related groups. The interests of the faculty often span several of the groups and hence faculty participate in the activities of more than one area. Interaction with outside departments is enhanced by the fact that 16 of the faculty hold cross-appointments. The major interactions within the University are with the Institute of Biomedical Electronics and Engineering, the Computer Science Department and the Department of Astronomy. External involvements include those with the University of Waterloo in computer/communications, with the Institute for Guided Ground Transportation at Queen's University and with NRC on Radio Astronomy.

Courses for credit can be taken in other university departments (e.g. physiology, computer science, physics, industrial engineering, pharmacology, etc.). In addition inter-university credits for graduate courses have been arranged where special graduate courses have been given partly at Toronto and partly at another university.

g. Physical Facilities

The outstanding facilities which the Department of Electrical Engineering has access to include computing power, computer research facilities and applications software and library. A good solid state fabrication facility also exists. The facilities for power devices and wave sciences appear adequate although the programmes in these areas are so diverse as to mitigate against a concentration of outstanding facilities.

The total department appears to be distributed over a number of buildings which prevents optimum communications and student interaction. Some of the area is somewhat outdated in regard to function and modern comfort.

Summary

The Electrical Engineering Department of the University of Toronto compares favourably with any of the major institutions in North America in regard to programme, calibre of staff and students and standards of performance.

UNIVERSITY OF WATERLOO

a. Coverage of Fields and Specialties

The Department of Electrical Engineering at the University of Waterloo offers work and conducts research which is concentrated in five major areas and two minor areas:

Computers and Communications - including schemata techniques for design of parallel systems, special purpose digital hardware, numerical machine-tool control, digital data networks in computer data communication systems, network switching and network topology, and general problems of interfacing between computers and users.

Control, Systems and Networks - including multivariable control systems relevant to industrial processes, traffic control as it relates to high-speed urban and inter-urban transportation, computer-aided design of nonlinear electronic networks, and related subjects.

Devices, Circuits and Materials - includes work on photodetectors, integrated circuits, high frequency transistors and modern semiconductor devices. General research in semiconductor material properties such as irradiation damage in silicon, oxidation of indium antimonide and impurity diffusion in semiconductors.

Power Engineering - including optimal control of generators and power systems, on-line computer control, machine simulation, load flow, and stability studies. Research is under way on problems in insulation engineering, with a large laboratory facility available including an H.V.D.C. simulator, and in power electronics.

Antennas and Electromagnetic Engineering - including radar systems, antenna arrays, interferometers and numerical methods for studying diffraction problems.

Bioengineering - limited to the application of solid-state physics to the physical mechanism of nerve conduction.

Electroacoustics - limited to the construction of a facility for numerical analysis of sound and noise, and the spectral analysis of noise.

As Table WA-1 will show, the last three areas have limited faculty attached to them. Three faculty members are in the areas of antennas and electromagnetic engineering. The bioengineering programme is a full-time effort on the part of Professor Wei, and the electroacoustics programme is the result of a special interest of Professor Keeler.

It should be noted that there is a Department of Systems Design at the University of Waterloo, and the interests of that Department do overlap to some extent with those of the Department of Electrical Engineering. Similarly, there is a Department of Computer Science within the Faculty of Mathematical Sciences, and there is also a considerable overlap of interests for certain individuals within these two departments.

b. Faculty

With a faculty of 37 (the exact number is difficult to establish due to sharing and also visiting appointments), the Department may truly be considered a large one, second in Ontario to the University of Toronto. The faculty members are relatively young, the number peaking in the range of 35-39 years, and the rank of associate professor has the largest number in it (full: 13, associate: 18, assistant: 6). Twenty-five of the 37 have grants and the average value of the grant is $9,770. The accomplishments of the faculty are mixed with a large number of "stars" of international reputation, but also a few relatively inactive faculty members. The distribution of faculty and PhD and master's students is shown in Table WA-1.

TABLE WA-1

(University of Waterloo)

Area	Number of Faculty	1972-73 Master's Candidates FT	1972-73 Master's Candidates PT	1972-73 PhD Candidates FT	1972-73 PhD Candidates PT
Computers and Communications	10	16	4	2	2
Control, Systems, Nets	8	4	3	6	1
Materials, Devices, Ckts	8	3	3	6	1
Power Engineering	7	6	3	6	1
Antennas and EM Engineering	3	4	0	4	0
Bioengineering	1	-	-	-	-
Electroacoustics	1	-	-	-	-
TOTALS	38	33	13	24	5

It should be noted that the Department's own projections list 20 PhD students in residence and 35 master's students in residence as being their five-year objective. This is accomplished, of course, with only 4 new PhD students being admitted each year.

In examining the distribution of PhD students in the various areas covered by the Department, it is surprising to see so few students in communications and computers. This may be understood by realizing that many of the students interested in such subjects may well be in the Department of Computer Science, or that this effort in the Department is relatively young and has not yet had an opportunity to develop. The relatively large enrolment in the power engineering programme makes it one of the largest in North America.

c. Nature of the PhD Programme

Like most other Canadian universities, admission is based on the student's performance at the master's level. Once admitted, he enters into a programme decided upon in consultation with his adviser and committee. There are no specific course requirements for the PhD degree beyond the master's degree, but the programme is decided upon for the needs of the particular student. In most cases, course work is prescribed. It should be noted that a similar scheme is used by a number of U.S. universities, such as Stanford University and Princeton University. A comprehensive examination is taken by the student within the period of 8 to 12 months after admission. This is a general examination covering the student's own background and also his proposal for doctoral research. After the completion of the thesis research, an examining committee is appointed with an external examiner included.

The faculty would like to enroll more Canadian students in their programme, but accept students from outside of Canada to fill the ranks.

It should also be observed that there is relatively less industry in the Waterloo-Kitchener region than in Toronto-Hamilton or Ottawa areas, and so there is less opportunity for the close relationship with Canadian industry observed at some other universities.

d. Enrolment Size and Distribution

With a competent faculty, an attractive and modern campus, and unusually well-equipped experimental facilities, there can be no question that the number of students now enrolled can be accommodated. This number might be increased to some extent, subject to obtaining a better balance between Canadian and foreign students, to be discussed in the next section. It is also to be noted that a large proportion of the students have been attracted to abstract or theoretical studies in the past, rather than to areas with possible application to the needs of Canadian industry. In the future, there should be greater emphasis on applied studies in high-technology fields, with consequent diminished attention to theoretical studies.

e. Student Body and Admissions

In 1972-73, the 24 full-time PhD students were distributed as follows: 5 from Canada, 14 from Asia, and 5 from other countries. Of the part-time PhD students 3 were from Canada, and 2 from Asia. Graduate students in the Department held 7 NRC scholarships, and there were 7 Commonwealth Scholars or equivalent, 2 Ontario fellowships, and 1 other major scholarship. The remainder are supported on some combination of demonstratorships and research grants, to a total of 57 supported.

This unusually high percentage of foreign students is not unique to the particular year under study, but has been characteristic of the Department in the past, so much so that it has attracted attention both inside and outside of Canada. It has also been the cause of problems in the manning of the undergraduate laboratories by these students. It seems clear that the Department should face up to this problem, and present some plan for transition to a situation in which a better balance between Canadian and non-Canadian students will be obtained. The continued attraction of a number of CIDA scholars is, however, to be encouraged.

Admission is determined at the master's degree level. It appears to be a satisfactory procedure, and it is working well.

f. Relationship to Related Disciplines and to the Profession

Cooperation exists with Mechanical Engineering in computer-aided manufacturing and with Systems Design in power systems studies. Informal cooperation exists with the Department of Computer Science, and that cooperation will become formal if the University is successful in winning a negotiated development grant in computer communications from the National Research Council.

There is cooperation with the University of Windsor in the area of high voltage and insulation research. The two groups have been jointly awarded a major installation grant from N.R.C. and regular exchange visits are planned. In addition, this group cooperates with Ontario Hydro in research, and has in the past worked with Hydro Quebec.

g. Physical Facilities

The building space occupied by the Department is modern and adequate for the near future. The total space used at present is over 50,000 square feet, with 25,000 square feet of this being used for graduate research and graduate student use. Not only are the buildings new and of modern design, but all laboratories are well equipped for experimental work by faculty and students.

Summary

The Electrical Engineering Department at the University of Waterloo has attained an excellent reputation for its research and graduates in a relatively short period of time. It suffers to some extent from isolation, and must expend effort in the future to maintain a close contact with industry not only in the Waterloo-Kitchener area, but also in the Toronto region.

The programme in the two areas of Bioengineering and Electroacoustics are marginal due to the limited manpower assigned to them. Since manpower needs for PhD degree holders in these two areas seem somewhat limited, the University should limit these programmes to the present level of activity, and should not hire new faculty or build new facilities to strengthen these areas.

UNIVERSITY OF WESTERN ONTARIO

a. Coverage of Fields and Specialties

The Faculty of Engineering Science at the University of Western Ontario is comprised of 5 groups which operate somewhat as departments. The main interest of the group most closely related to electrical engineering is applied electrostatics - development of electrostatic precipitators, electrical phenomena in corona discharges, electrostatic separation of mineral ores, applications to chemistry and the environment. A number of highly applied projects are in progress, most of which are being performed in collaboration with the Chemical and Biochemical group and the Material Science group of the Faculty of Engineering Science. In addition, 1 1/2 members of the electrical engineering group participate in the Centre for Radio Science - a separate interdisciplinary organization reporting to the University Senate and involving primarily participants from the Physics Department.

The research in applied electrostatics, although highly specialized, has under strong leadership attracted considerable interest from industry and government. The contribution of the electrical engineering group to Radio Science does not appear to be of significance.

b. Faculty

The total faculty related to electrical engineering is seven, 3.5 of whom are in the area of applied electrostatics, 1.5 in radio science, 1 in biomedicine and 1 devotes all his time to teaching administration. The electrostatics group has one full professor and 2.5 assistant professors; the radio science group comprises 1 associate professor and 0.5 assistant professors. Only one member of the faculty has any significant international reputation.

c. Nature of PhD Programme

A PhD programme is offered both in applied electrostatics and in radio science. The degree requirements include six courses, a reading knowledge of a second language, a comprehensive examination and a thesis.

The range of courses available, although adequate in the general area of applied electrostatics, does not give sufficient coverage to basic areas of electrical engineering. This has resulted in particular difficulties for graduates in successfully seeking employment and in adjusting to job requirements.

The programme seems conscientiously administered but appears too narrow in scope for doctoral training for electrical engineering. Whether the programme in Chemical Engineering or Material Sciences is adequate is not within the competence of the consultants in electrical engineering to determine.

d. Enrolment Size and Distribution

The enrolment in the Doctoral programme has been very limited with only 4 graduates since 1968. The group would like to see additions at the rate of 2 PhD candidates per year in electrostatics and 1.5 PhD candidates per year in radio science. The enrolment is given in Table 1-WO .

TABLE 1-WO

Area	Staff	1972/73 MSc Candidate		1972/73 PhD Candidate	
		FT	PT	FT	PT
Electrostatics	3.5	6	2	2	0
Radio Science	1.5	0	0	0	0

e. Student Body and Admissions

The limited number of candidates for the PhD degree makes any generalization about the student body difficult. It appears that the students are either from the immediate local region or landed immigrants. The majority are supported on research grants and demonstratorships. There has been one NRC scholar among the group in the last 5 years.

Admission to the PhD programme requires graduation from an approved university with at least a B standing. Initial admission to the master's programme is the practice usually followed.

f. Relationship to Related Discipline and the Profession

The applied electrostatics group works closely with the Chemical Engineering group and the Material Sciences group within the Faculty of Engineering Sciences. In fact, it is often difficult to identify the major electrical engineering component of some doctoral programmes. These interdisciplinary research programmes have attracted support from industry and government.

The relationship with the Centre for Radio Science is not strong or well developed.

g. Facilities

Taken in combination with the Chemical Engineering and Materials Sciences groups, a considerable amount of laboratory space and apparatus is available to the electrostatics group. Similarly, although the group itself has no facilities for radio science, the facilities and field station of the Centre for Radio Science are available.

Summary

Good research is being conducted by the Electrostatics group in conjunction with other groups in the Faculty of Engineering Sciences. However, the breadth of capability of the faculty in Electrical Engineering together with the number and scope of courses in important areas of electrical engineering available to the student, are insufficient for appropriate training for the doctorate in electrical engineering. The radio science component of the Electrical Engineering group is not up to the strength required to give a PhD degree.

UNIVERSITY OF WINDSOR

a. Coverage of Fields and Specialties

The only fields in which the Department of Electrical Engineering offers doctoral research are:

Electric Power - including high-voltage studies, with emphasis on breakdown phenomena along dielectric surfaces in vacuum and breakdown in compressed gases and in dielectric liquids; propagation in E.H.V. systems, and studies of magnetic materials.

Systems and Signals - which covers signal processing theory and applications, including studies of communications systems performance and multi-dimensional digital filtering; applied systems theory, emphasizing computer-oriented analysis and simultation of physical processes.

b. Faculty

The faculty consists of 9 full-time members of staff, 4 of whom are professors, 1 associate professor, 3 assistant professors; one holds an unspecified faculty rank while completing his doctorate at Windsor. Only one other does not hold a PhD degree. Only the three most junior members of faculty hold degrees at any level from Canadian universities. The 4 professors all hold NRC operating grants, averaging $9,693; three other professors hold grants which average $4,250. There is a broad distribution of faculty age although only one retirement can be expected within the next five years.

There is a strong group spirit in the prosecution of the research objectives. All members of faculty are involved in the research, four with principal interests in the power group, and five in the signals and systems group, although the corresponding proportions of research and graduate time have been stated by the Department to be 4.65 and 4.35.

c. Nature of the PhD Programme

The doctoral programme is conventional in form, involving both course work and research. Course requirements include a minimum of 8 semester hours beyond the master's degree. In addition, each student is expected to attend all departmental seminars, and is required to give a minimum of three seminars on which he is assessed. The doctoral research is supervised by a committee of members of the Department. The overall administration of the graduate programme is formalized to a greater extent than was apparent in most other universities.

The courses available are necessarily limited in number, and tend to reflect the research interests of members of the Department more than may be desirable in a small department.

Beyond the usual examinations in courses, the doctoral student must satisfy his committee at the beginning of each academic year that he is qualified to proceed, possibly by written or oral examination, and he must pass a comprehensive examination upon completion of all course work. There has been some latitude in this requirement in that it could be satisfied by passing a written or an oral examination or by presenting a seminar approved by the student's committee on a subject outside his major area. The latter avenue is no longer open. This examination establishes his candidacy for the degree. The Department is very selective at this stage; to date, only 5 students have completed the PhD, and 6 were refused candidacy.

The final oral examination is conducted under the auspices of the Department, not the Faculty of Graduate Studies. It is required that an external examiner report on the dissertation, and, if possible, he is in attendance at the thesis defence.

There is a 6-year limit on time to complete the doctorate beyond the master's degree.

d. Enrolment Size and Distribution

Of the 7 doctoral students in the Department in 1972-73, our data shows that 3 are in the power field and 4 in signals and systems. Six of those students are full-time. The Department anticipates having approximately 8 full-time and 3 part-time students by 1977-78. No diversification of major research fields is planned, although greater emphasis on development of the systems group is indicated.

e. Student Body and Admissions

Over the period 1968-73, Windsor had a higher proportion of its graduate students supported by NRC scholarships than 5 other Ontario universities. Another indicator of student quality may be taken to be the record to date of mean time to complete degree requirements beyond the master's (37 1/2 months), which is bettered only by Toronto.

The consultants were impressed by the maturity and competence of the doctoral students interviewed, more so than in any other institution.

The formal requirement for admission to the doctoral programme is a master's degree in Applied Science, Engineering or Pure Science (in a related field). For the master's programme the requirement is the Bachelor's degree in Engineering or Applied Science with at least 2nd-class standing. The Department demands more than the minimum requirement.

f. Relationship to Related Disciplines and to the Profession

There does not appear to be significant interaction between the Department and related fields within the University, although the Faculty of Engineering is regrouping its activities in three areas, systems, process design and structures, the first two of which afford good opportunities for interdisciplinary work. There is some collaboration between the Departments of Electrical Engineering at Windsor and Waterloo, particularly in the research on high-voltage insulation. The power group has affiliations with the Ontario Hydro and Windsor Utilities commission, and has had some research support from the latter. These affiliations have not, however, resulted in major support, and some effort is required in this direction by both groups.

g. Facilities

The Department has an adequate allocation of space for its present graduate programme, although part of that space now being developed for the high-voltage laboratory is not in the most convenient location. The experimental apparatus available, if not entirely adequate, at least provides the basic equipment necessary for work in the two major fields. There was no evidence of expenditures on non-essential items. Both computing and library facilities, the latter supported by excellent loan services from nearby U.S. institutions, are good.

Summary

In spite of the small size of the Department and the relatively low level of funding, the doctoral programme at Windsor has strengths not apparent at other institutions. The Department has limited itself to two major fields, and pursues its research in those fields cooperatively, with all faculty members participating actively. There is sufficient breadth within those fields to provide doctoral training that will produce a research engineer with the flexibility to meet the technological challenges of the future.

The programme is well-planned and rigorously and conscientiously administered. The Department has a good record of success in attracting competent students. There is some shortage of supporting courses available, and there is a lack of industrial contacts, particularly in the signals and systems group.

APPENDIX B

DISCIPLINE GROUP RESPONSE

COMMITTEE OF HEADS OF ONTARIO ELECTRICAL ENGINEERING DEPARTMENTS

Response to the ACAP Consultants'
"Report on Doctoral Programs in Electrical Engineering in Ontario Universities"
September, 1973

December 17, 1973

GENERAL

The consulting team deserves commendation for its comprehensive assessment, completed in a rather short time interval, of the state of doctoral work in Electrical Engineering in Ontario. Their assessment of the supply and demand situation over the next five years is most welcome. It is consistent with the view put forward - with perhaps less evidence - by this committee in its report of April 25, 1973 (Appendix 2 of the consultants' report). We note with satisfaction the consultants' reference to need as well as demand. We note also their perceptive view that demand for doctoral graduates in engineering science means, for the most part, a demand for doctorates in the electrical/ electronics area. Correlated with this they state that "a large portion of engineering science baccalaureates take their doctorates in electrical engineering".

The consultants' assessment of demand for Electrical Engineering doctorates in the near future, together with the recommendation - subject to the constraints of available supply, satisfactory minimum standards, and the capacity of the universities - that there be no quota on the production of doctorates, are the dominant and welcome features of the report.

The report draws attention to areas of weakness in the system. This is not surprising. We would not expect the consultants to have found perfection and would have regarded as suspect any report that was too fulsome in its praise. But, in the main the picture is one of a strong, vigorous set of programs which have evolved to their present state of excellence - as pointed out in our April report - in a relatively short period of time. Some situations have been considered by the consultants as reflecting serious weakness, and they have come to some rather drastic recommendations. Though we recognize that their assessment may in some respect have foundation in fact, we do not believe that the recommendation of program curtailment is justified. We believe that more harm than good will be done by cutting off any existing program, that the general standard of Electrical Engineering education may suffer at the bachelor's and master's levels should this occur, and that corrective action would be impeded.

We regard the role of the discipline group as central in the continuing process of rationalizing the system and monitoring standards of quality. We welcome the positive comments of the consultants on the role of the discipline group, and take some pride that our meetings and activities to date have assisted in bringing the system to the point where its main features have elicited positive response from this distinguished outside group. We would expect that our role can be strengthened by the report, and that we may provide the continuity needed for self-discipline among the various Ontario departments.

Early in the assessment procedure we took the view - expressed in a letter on May 31, 1972, from the Chairman of our group to Professor M.A. Preston of ACAP - that "we would now wish to take the same position taken by the Chemical Engineering and Mechanical Engineering groups and proceed with assessments without any formal subdivision of the field into a set of subdisciplines". The consultants in Chemical Engineering and Mechanical Engineering have accepted this stand by the discipline groups. Our own consultants, if they were aware of this position, have not accepted it. We regret this. Instead they have opted to rate the universities on the basis of a set of seven research fields of their own choosing. We question the validity of their choice of fields. In some cases the "fit" between these chosen fields and those specified by a department is less than close. The assignment of staff, doctoral students, funding and facilities to these seven fields has been determined arbitrartly by the consultants and in some cases their judgement in this matter is open to question.

THE CONSULTANTS' RECOMMENDATIONS

The remainder of this response will be devoted to specific comments on and reactions to the ten recommendations set forth in the consultants' report. These will be dealt with in the order in which they appear in the report.

1. Supply and Demand

We agree with the recommendations of the consultants that there should be "no limit or quota on production of doctorates in electrical engineering". We believe that the figures set forth in our earlier report on projected enrolments are consistent with this recommendation. They are consistent in the sense that, using the criteria set forth by the consultants - namely the availability of capable graduate students, the maintenance of adequate standards, and the existing capacity as measured by staff and facilities - together with the constraints already existing (which have been imposed in the main by governments) - no over supply situation is likely to develop. We believe that the chapter in the consultants' report on supply and demand for doctorates is a valuable contribution, and that their view of the demand, and the need, for Ph. D. 's is realistic. We believe that pessimistic views of demand, based upon surveys of industrial employers' views of the future are not necessarily reliable. We surmise that, had such surveys been made of industrial, governmental, and academic employers five years ago the results would have indicated that a large number of those who have graduated with Ph. D. 's in the interim would have been without employment. In fact there is no history of unemployment of Ph. D. graduates in that period.

2. Relevance of Areas of Graduate Research

We endorse the recommendation that the heads of Ontario departments of Electrical Engineering identify on an annual basis and report to industrial groups research areas considered relevant to Canadian needs. We believe that for adequate implementation of this recommendation the discipline group will require a source of funds not presently available to it.

3. Administration of Doctoral Programs

We agree with the consultants that high standards of admission should be maintained, and would support a recommendation that high standing with proven research ability be required. We do have some doubt about a rigid interpretation of the phrase "first class standing". We would prefer the use of words such as "very high academic calibre". Most universities, including the best ones, do not require first class standing in the rigid sense. When students reach the stage at which they consider application for doctoral programs most of us expect that an element of judgement is required on the matter of admission. Some students with the very highest standing in their undergraduate work may prove to be quite inadequate for doctoral work, whereas others with good, though not strictly speaking first class, undergraduate standing prove themselves, in a variety of ways that are subject to quantitative measurement as well as subjective judgement, to have the capacity for doctoral work.

We generally concur with the recommendation that criteria for the qualifications of faculty to supervise doctoral theses should exist. We do believe it would have been helpful had the consultants cited in their report reasons for this recommendation, or examples of the nature of the criteria that they might have in mind.

We naturally support rigorous administration of the doctoral program.

While we support in principle the objective of decreasing the average time to completion of the doctoral degree, we cannot see that, as a practical matter, this would have great effect upon the existing doctoral programs. The mechanism by which the provincial government funds universities for registered students in graduate programs already places time limits on funding which provides sufficient incentive for the universities to endeavour to place limitations on the duration of doctoral programs.

4. Carleton University, McMaster University, University of Toronto and University of Waterloo

We support the recommendations of the consultants that these four universities be encouraged to carry out their five-year plans, including some modest increase in student enrolment. This recommendation is, in the main, consistent with the proposals set forth in our report of April 25.

5. University of Ottawa

The position taken by the consultants on the University of Ottawa - namely that it stop accepting students for the doctorate for the period 1974-78 - is inconsistent with our own view as presented in April. Consideration of the report in the Appendix (A-90 to A-94) leaves us with the view that the consultants' recommendation with respect to the University of Ottawa is unduly drastic. The University's proposals for doctoral work, which were supported by the Discipline Group, were relatively modest. They were not expansionary. The consultants have pointed out that two members of the faculty enjoy international reputations, and that the department attracts students "of high quality".

We recognize that there may be deficiencies in some aspects of the program at the University of Ottawa that require corrective action, but we understand that the university had recognized this prior to the visit by the consultants, and that appropriate action has already been initiated. The comments in the consultants' report should assist the department head in his efforts to continue the corrective process. We strongly believe that the implementation of the consultants' recommendation would harm this process. It would make the retention and attraction of high calibre staff difficult, would undermine the confidence of prospective students, would discourage sources of outside support for research, and in general would jeopardize the outcome of any future review, such as proposed by the consultants after a five year period.

6. Queen's University

We support the recommendation that Queen's concentrate for the present in the fields of Communications and Systems. Queen's has, at the doctoral level, followed a pattern of concentration in these fields, though not to the exclusion of doctoral work in Electronics and Energy Processing.

We do not regard the proposals made by Queen's relative to future doctoral enrolment as unduly expansionary, and we see no reason for excluding this University from the group of four for whom "some modest increase" is regarded as acceptable.

We support and obviously have no reason to oppose the recommendation that Queen's improve its research facilities in the Communications and Systems areas in whatever manner it can manage.

We believe that there is evidence of substantial interaction with government and industry and that what the consultants have regarded as geographic isolation is unduly emphasized.

7. The University of Western Ontario

In view of the quantitative measures of strength set forth in the "Average Faculty Characteristics" of Figure 4.9 (page A-53) of the consultants' report, as well as the modest proposals made by that university for doctoral enrolment in the near future, we believe that the recommendation of the consultants that Western cease to offer the doctorate in Electrical Engineering is inappropriate. The program, designated as an Engineering Science program, is strongly interdisciplinary and a proper assessment requires consideration of all inter-related aspects of Engineering Science.

The program at Western, particularly the work in electrostatics, has achieved a considerable measure of recognition on an international basis. We regard this work as a unique and important part of the spectrum of opportunities for doctoral work in Ontario. The work is relevant to industry and well supported. It is an interdisciplinary program, and as such is commendable.

8. University of Windsor

We support the recommendation of the consultants that Windsor continue with its doctoral work in the fields of "Power" and "Signals and Systems". The recommendation is quite consistent with our own Discipline Group view of April, and with the plans of the University of Windsor. Any review of the Windsor program should be part of a general review process conducted by the discipline group - as proposed in our recommendation at the end of this response.

9. Coordination

We agree with the consultants that meetings of department heads and chairmen (or graduate coordinators) should continue to be held on a rotating basis at the various provincial institutions. This was the practice of the Committee of Heads of Ontario Electrical Engineering Departments up to the time when the ACAP assessment procedure became relatively high pressure business. Under these circumstances the group has found it expeditious and economic to have its meetings in Toronto.

The discipline group welcomes the suggestion that it should aim to determine, by mutual agreement, areas of specialization for the various departments in the province and to coordinate development plans for new areas.

10. Support for Foreign Students

Insofar as we are able to determine the intent of Canadian immigration policies we will continue to do our utmost to see that our departmental practices are consistent with these policies and, of course, consistent with federal and provincial regulations.

RECOMMENDATION

We recommend that future reviews of any program in Electrical Engineering be conducted by the discipline group. This proposal is consistent with the recommendation (No. 9) of the consultants that the discipline group play a strong role in the coordination of graduate studies.

APPENDIX C

UNIVERSITY COMMENTS

Comments appear from Carleton, McMaster, Ottawa, Queen's, Toronto, Waterloo, Western Ontario and Windsor.

CARLETON UNIVERSITY

RESPONSE TO FOUR ACAP ASSESSMENTS ON ENGINEERING

Introduction

Carleton takes the view that groups of disciplines should be evaluated before a clear picture of the situation within a single discipline can be obtained. Reports on any one component considered in isolation could lead to an erroneous judgement and unwise and precipitate action. Three consultants' final assessment reports have now been received for engineering disciplines in which Carleton is actively involved: Civil Engineering, Electrical Engineering, and Mechanical and Aeronautical Engineering. A fourth report deals with Metallurgical and Materials Engineering, of less direct concern to Carleton, while a fifth report, not yet received, will deal with Chemical Engineering, a discipline not represented at Carleton.

This response will address itself to the four reports which have been received and examined to date. We may wish to add further comments when the fifth report has been studied.

We sense a good deal of unanimity on a number of fundamental questions among the fifteen consultants involved in the four reports so far received, a communality of viewpoint which we share and endorse. We believe that Engineering has been most fortunate in having the assessments carried out by a group of consultants whose international stature, valued judgement and perspective give authority and credibility to their studies and reports. In general then we accept their findings and subscribe to their recommendations with only a few exceptions to be noted later.

In this response we shall deal first with those matters which we believe to be basic and general in nature and leave until the end our views on specific points raised in individual reports.

Matters of a Fundamental or General Nature

1) Control of Student Numbers:

The four reports are unanimous in their opinion that previous estimates of the demand for engineers with doctoral degrees, notably those in the Lapp Report of 1970 and the report for CEMC of 1973, have erred seriously on the low side. They point out that there is no evidence of difficulty in obtaining jobs by students close to graduation, nor do they foresee difficulties in the future except for those which normally occur in highly specialized areas.

The consultants reject the notion of quotas applied to departments to control student numbers, in part because the demand seems likely to exceed the supply than the reverse, making quotas unnecessary, but in the main because they feel that other means of control are to be preferred. The report on Electrical Engineering puts it this way: "The number of doctorates granted in electrical engineering (should) be determined by:

(i) availability of qualified students

(ii) maintenance of adequate standards by the universities, and

(iii) the existing capacity (staff and facilities) of the universities for giving adequate training." The Mechanical consultants refer to emerging natural controls and go on to say: "We would wish the resources of the present system, which are predicated principally on undergraduate requirements, the market demands, the quality of the programme and the good judgement of the departments to determine the total number within the system."

Carleton subscribes fully to these views. We believe that rather than through centrally imposed quotas or limitations the universities individually should control numbers by restricting admission to students showing high promise and by maintaining adquate standards. The latter together with the market demand will provide an adequate control. We would be prepared to support the development and adoption of an evaluation scheme, such as the scholastic index used at Carleton, which can be applied across all disciplines and which could be used in the monitoring of admission standards which we believe should be a matter between a university and OCGS. We believe, however, that the interpretation of these standards for individual student cases should be left to the informed judgement of the university concerned.

2) <u>Quality of Existing Programmes, Suggestions for Change</u>:

From their comments on the quality of the Ph.D. programmes for the system generally, it is clear that the consultants believe it to be quite acceptable. The Civil consultants point out that "the system provides a good quality coverage of the field and specialties without undue overlap on a regional basis." Comments on individual universities draw attention to departures from the norm in both directions.

A common theme running through the reports is the need for greater flexibility in the future. The Metallurgical and Materials consultants state it this way: "As Canadian industry becomes more sophisticated and has to rely on more advanced technologies, it will have to learn how to fully utilize the talents and skills of Ph.D. graduates and the universities will have to learn how to develop Ph.D. programmes which produce imaginative engineers capable of responding to these new opportunities." These consultants also recommend that programmes be so designed as to permit graduates from other specialties to change specialties as they commence Ph.D. work.

The consultants also show a degree of consistency regarding the need to shift the emphasis in Ph.D. programmes to meet the situation of the seventies. The Electrical consultants state it this way: "The education of Ph.D. students in areas of national need is a more efficient use of resources than is a random choice of fields followed by a period of retraining." In relating it to their field, the Civil consultants state that there should be "less stress on traditional areas, particularly structural engineering, and more stress on multidisciplinary education, environmental engineering, and transportation." The Mechanical consultants recommend a greater emphasis on production engineering and design.

Close contact between universities and industry is felt to be important by all the consultants and individual universities have been singled out for commendation where this contact is regarded as exemplary while others have been asked to improve in this respect.

Once again Carleton accepts the findings of the consultants on the quality of the existing programmes and their views on the nature of Ph.D. programmes required for the immediate future. We feel that we have already made considerable progress toward achieving the desirable objectives set out by the consultants and that we have received adequate recognition for this in their reports.

3) Critical Size:

The Engineering consultants are far less concerned about the concept of critical size than the consultants who carried out some of the earlier planning assessments, and show as much concern for the disadvantages of "bigness" as of "smallness." The Engineering consultants place their primary emphasis on the quality of the student and of the faculty rather than on size, a view which we heartily endorse.

The Mechanical consultants take the strongest stand against the notion of critical size. While admitting the advantages enjoyed by a large group, they go on to express their view that "a drawback to the large group is the difficulty of adapting to change" and further that "the groups in the smaller departments often displayed an original point of view and a willingness to adapt to change that was not apparent in the larger and longer established departments." They found more cross linkages between departments and a greater tendency to establish outside contacts with government and industry in the smaller faculties. They conclude: "In our view no creative group, and no capable individual within such a group should be denied support because it is small." The Civil consultants echo these views: "Size is not a sufficient criterion for judging whether a school can offer a Ph.D. programme" and also "there is no a priori reason why a small school cannot provide as satisfactory an environment for the student as a large school."

The Electrical and Metallurgical and Materials consultants are not as definite on the matter of critical size as the Civil and Mechanical consultants. The Electrical consultants felt that a desirable size for a department fell in the range from 10 to 20 faculty with from 10 to 20 students enrolled but expressed the view that "high standards of excellence with emphasis on quality rather than quantity will pay off in the long run." The Metallurgical and Materials consultants draw attention to the contrast between the British approach to Ph.D. education centered around the thesis and requiring only one good faculty member and the American view that a department needs to be sufficiently large to provide a proper range of courses because of the importance given to course work in the American approach. The consultants themselves took the position that students should be taught by members of the basic science departments as well as by Engineering faculty members and that the critical size of the core depends a great deal on the strengths in related disciplines. The latter factor seems to have been ignored by some of the consultants who assessed the non-Engineering disciplines.

As indicated above, Carleton is fully in agreement with the position on critical size taken by the Engineering consultants and does not support the views of the Chemistry or Economics consultants nor ACAP's views on this matter.

4) Proportion of Foreign Students:

All four of the reports under review make reference to the enrolment of foreign students in the graduate programmes at Ontario Universities.

The Electrical consultants noted that the percentage of doctoral students with first degrees from Canadian universities was consistently in the range from 47 to 51 over the past five years. They believe an ideal mix should involve students with a variety of backgrounds coming from various universities and should include some students from foreign countries. The latter they feel should be in the minority and they suggest 25% as an appropriate proportion. The Civil consultants expressed concern also at the low percentage of full-time Ph.D. students who had obtained their first degree in Canada but remarked also that the percentage was much higher for part-time students and suggested that part-time studies should be encouraged.

The Mechanical consultants, while noting a similar proportion of non-Canadian first degree students to those mentioned above concluded that we cannot count on Canadian undergraduate schools to provide candidates in sufficient numbers and that we must continue to rely on students from abroad. The latter would likely decrease in number in the future due to recent policy changes with respect to immigration and financial support for students without landed immigrant status. They suggest that support for such students should come from appropriate federal agencies such as CIDA.

The Metallurgical and Materials consultants find that "Canadian industry unable to fill its vacancies with Canadian graduates of Canadian origin has preferred to import graduates from British or Australian origin rather than employ Canadians of Asian origin." They recommend an intensification of efforts to recruit a larger proportion of Ph.D. students from the graduates of Canadian universities.

Carleton is in agreement with the consultants concerning the desirability of having a mix of students from different universities in Canada and from foreign countries and in having a reasonable balance between Canadian and non-Canadian first degree holders. The problem of foreign students is usually expressed as one of controlling their number. We believe that the recent immigration and financial restrictions imposed on this group is likely to overshoot the mark and the problem in the future may well be one of too few rather than too many foreign students. A more serious problem is that of too few graduates of Canadian schools embarking on Ph.D. work.

Comments on Some Specific Matters

In this section we wish to deal with some specific issues raised in individual assessment reports.

1) Civil Engineering Doctoral Planning Assessment:

The references to Carleton University throughout this report are generally favourable and on the whole we like their conclusions and recommendations. There are, however, one or two points we wish to question.

In Recommendation 3 the consultants suggest "there is a case for more consistent requirement of acceptance for Ph.D. students between universities." We are uncertain as to the meaning of this since it is not discussed in the body of the report. We have expressed the view earlier that there should be a system, such as Carleton's scholastic index, for evaluating students across all disciplines, and that OCGS might monitor standards of admission generally. We do not see the need for an external person on acceptance committees but continue to support the position that there should be external examiners on thesis committees.

We cannot accept the proposal in Recommendation 5 concerning the collapsing of the Ph.D. B.I.U.'s into the undergraduate B.I.U.'s although we can support the objective. We believe that a major re-examination of the formula for providing operating funds to the universities is called for, not just minor adjustments to B.I.U. weightings.

We do not see the necessity for the further proliferation of degree designations which would result from the introduction of the Doctor of Engineering Degree included in Recommendation 12. We support fully the consultants' concept of a range of possibilities for a doctoral thesis, from the mathematical or theoretical at one end to the design or application-orientated at the other end, but we believe the requirements for the Ph.D. should be flexible enough to permit this as is the case at Carleton.

2) <u>Report on Doctoral Programmes in Electrical Engineering in Ontario Universities</u>.

For the purposes of assessment and reporting, the consultants have combined Carleton's departments of Electronics and Materials Engineering and Systems Engineering under the discipline title of 'Electrical Engineering.' Their comments, conclusions and recommendations apply uniformly to our two departments. We regard this report as a highly competent and thorough piece of work. The analysis in the earlier sections prior to the evaluation of departments gives to the whole a degree of credibility that is probably unique in such reports.

Carleton University has received a uniformly favourable assessment in Electrical Engineering. The Ph.D. programmes in both departments are considered to be "strong." The interaction of Carleton with laboratories and firms in the Ottawa area is described as a "model" while our programmes are praised as having "unusually high contemporary relevance."

We intend to pursue our proposed five-year plan for the graduate programme in Electrical Engineering; we believe that our present organization into the two departments of Electronics and Materials Engineering and Systems Engineering is the most appropriate and effective for our purposes and intend to maintain this organization.

We have noted the general recommendation that only students showing high promise for graduate work should be accepted into the Ph.D. programme. We endorse this recommendation.

We plan to aim for the small growth in graduate student numbers proposed in the five-year plan, but note that in the consultants' view this growth is modest. We shall allow ourselves to be responsive to the applications which we receive from well-qualified students. We expect that our growth will be limited to a natural and non-excessive rate by the limited availability of good applicants.

We believe that it is possible to increase the scale and effectiveness of our associations with laboratories and firms in the Ottawa area and shall endeavour to exploit further such interactions.

The recommendation that greater use be made of graduate courses given at the University of Ottawa is accepted. The establishment of a close working relationship over the last two-year period has made the sharing of course offerings and facilities a natural outcome which it is intended to exploit.

We accept the report of the ACAP consultants without reservation. We consider the assessment to have been fairly and thoroughly done and believe that the report as a whole will be of considerable benefit to the Electrical Engineering profession in Ontario and Canada.

3) Report of the Mechanical Engineering Consultants:

We accept the ACAP consultants' report on Mechanical (and Aeronautical) Engineering without reservation. We consider it to be a valuable, authoritative, well reasoned document. The report is thoroughly credible because of the competence and international stature of the consultant team and the excellent overview they provide.

We accept the consultants' argument that, because "the developing market could easily absorb double the rate of output (presently about 30 Ph.D.'s/year in Ontario) during the next five years" and because of the serious undersupply of qualified candidates, assigned quotas for the Ontario system would be meaningless.

We agree that adequate capacity and quality exists within the department and that decisions about specific research areas should be made within the individual universities. We accept the criticism that excessive effort has been devoted to "traditional and classical areas of research" and that our efforts should continue to be re-directed towards research more pertinent to the practice of Mechanical and Aeronautical Engineering. We agree that the relevance of the research work would be enhanced if support were made more dependent on contracts from high technology industry and appropriate federal government departments.

We intend to pursue our proposed five-year plan and strengthen our contacts with industrial and government laboratories. We will explore the possibility of establishing an industrial research institute (or an office of industrial research) since these institutes are noted as having a highly beneficial effect on the research of the faculty and graduate students.

We applaud the recommendation that a good Ph.D. programme should provide breadth by means of well balanced course work and depth by means of a thesis involving substantial research on a specific and topical engineering problem. Doctoral graduates from such a balanced educational programme will be able to move into industry and tackle problem solving on a broad front.

Conclusion

We hope that it will be clear from the foregoing that we find the reports generally quite acceptable and can endorse all their major conclusions and recommendations. We regard the specific points on which we disagree with the consultants to be minor in comparison to the aggregate of the issues on which we agree.

G. R. Love
November 12, 1973

RESPONSE OF McMASTER UNIVERSITY

TO

REPORT ON DOCTORAL PROGRAMS IN ELECTRICAL ENGINEERING

AT ONTARIO UNIVERSITIES

In its overall view, its thoroughness of examination in reporting thereon, its contributions to the problems of highly qualified manpower planning, its careful evaluation of present Ph.D. programs appealing to high standards of capability and quality, and its contributions to planning of the immediate future of the Ontario system in Electrical Engineering, this report is worthy of much commendation. It can serve well as a model both for its understanding and its forthright handling of its wide terms of reference, and for the organizational arrangement in the presentation of the study and its recommendations.

The thorough analysis of the manpower situation carried out by the consultants has verified on a broader basis the experience we have had in our local situation: Ph.D. graduates are employable and employed; demand continues, and new needs arise. The twenty-six pages devoted to the well-developed appraisal of current knowledge of the past and current employment, of the projected supply, demand and need for Ph.D.'s in Electrical Engineering, provide a most convincing rationale against imposition of any reduction in the intake of Ph.D. candidates in Electrical Engineering. The consultants have used both Canadian and U.S.A. data and have paid special attention to the information made available to them by the Ontario universities. They have recognized that the Canadian scene is more sensitive and indeed reactive to the U.S. situation; and have noted well the place taken in that Canadian picture by the Ontario engineering schools. We concur most heartily in their strong criticisms, validated by the statement of specific omissions and errors, of the CEMC report on "Supply and Demand for Engineering Doctorates in Canada". Their statement, page A-17, "Thus predictions of demand are very uncertain at best and almost invariably are grossly in error. It is unfortunate that such gross estimates, uncertain as they are, often are given great quantitative significance in arriving at major policy decisions", is a conclusion we support most emphatically. At the same time, the authors make a conscientious effort to correlate the CEMC report models with their own data and calculations in a useful fashion. Importantly, the authors emphasize the need for a responsive enunciation of research fields that give a high position to need and relevance - a conclusion which we support unequivocally and have endeavoured to use in the past but will try to utilize even more visibly and effectively in the future.

The report's succinct linkage of national policy to other factors relating to doctoral programs (Chapter 3) deals forthrightly with important issues. We do agree with their opinions on critical size, on interaction with industry, on relationship to undergraduate programs and on foreign students.

We are particularly appreciative of the responsible manner in which the assessors dealt with their instructions to make a quality assessment. In the twenty-eight pages in which they have evaluated the doctoral program situation, they have made extensive use of the data provided and have supplied important and penetrating analyses. These will be most beneficial in policy and procedural developments for the immediate future for our institution, as we are certain they will be for the other universities. The assessors' efforts to select important indicators based on the data supplied and to make both relative judgements and specific comments for each department are most helpful in planning for each school as well as for the provincial system. Since almost all their recommendations arise from this important culminating Chapter 4 of the report, we will respond briefly to each of the recommendations. However, it should be noted in an overall sense that we consider that the assessments reached have been based on the grouping of a series of indicators, with the selection and delineation of which we agree. The attempt by the assessors to include a rate of change based on their observations is an equally acceptable approach that will be of added value in re-assessment in ensuing years, whether it is carried out by the discipline group or internally.

Comments on specific recommendations:

Recommendation #1. We agree fully with this statement, including the listing of the determining factors.

Recommendation #2. We agree with the importance of relevance in selecting with care the research topics, and will support the cooperative methods proposed to enhance dialogue among the departments and with industry. We feel that this recommendation is worded in an appropriate fashion so that departments and individuals still have a reserved right to be estimating what will be relevant in the future as well as accepting, critically, what is commonly agreed to as relevant now. Even with the risk of sometimes being wrong in exercising such a freedom of choice, it seems to us that some elements of technological forecasting and relatively unfettered choosing of research topics must be retained.

Recommendation #3. While agreeing with the emphasis on the increasing of standards generally, we cannot support on a completely arbitrary basis the admission of only "candidates with first-class standing and with proven research ability". Our University policy has been recently changed to a more restrictive one of admitting only students with upper second-class or first-class standing. Such admissions apply to both the Master's and Doctoral programs. An opportunity to permit admission of the truly unusual and unconforming, but obviously able, student must be retained, as must be the right to discriminate, through experience, amongst the varying standards at the Bachelor's level across the country. Our normal practice is to admit only students from the Master's program into Doctoral work and in this way it is possible to meet the proposed requirement of proven research ability. We would therefore claim that the element of proof in this category must retain a wide degree of flexibility and judgement.

At McMaster we have tried to recruit high quality faculty who can function as effective teachers of graduate students, including doctoral students, and have not formally distinguished faculty for doctoral supervision. Thus we feel that we meet the spirit of the recommendation in this report through our high recruiting standards for faculty, an emphasis on joint supervision of students, and our right to prohibit a faculty member from Doctoral student supervision where appropriate. We support the concept of rigorous administration of a Doctoral program, and claim that, with the periodic reviews normally given, we have such. We concur in the appeal to reduce the average time for Ph.D. work, and will examine our operations carefully with this in mind.

Recommendation #4. We are pleased to note McMaster's position in this recommendation, and will continue to work to maintain and build ever-better grounds for such a conclusion.

Recommendation #5 to #8. These recommendations speak to other universities, and we offer no comment other than that we perceive these recommendations to be in general most consistent with the supporting evaluations in the report as well as with the bases of such evaluations which are enunciated.

Recommendation #9. We agree with this recommendation and will support moves towards its implementation.

Recommendation #10. The matter of concern here is one that will continue to be watched closely. We concur.

Regarding the assessment of McMaster University as it appears in Appendix 3, there are five specific matters we wish to raise, some of which have come to light through discussion in the Electrical Engineering Discipline Group.

1. Several research laboratories were omitted in our University submission on the building space available for graduate research. The net assignable square feet of research space available is 8,559 sq. ft., not 4,010 sq. ft. as previously reported. Appended is a listing of the research areas.

2. The research grants summary did not include the amount of the Negotiated Development Grant attributed to the 1972-73 period. Hence, we attach a summary of research grants for 1972-73 which shows a total of $381,579 awarded for that year. The corrected allocation of funds to research groups is included.

3. We submitted a preliminary five-year plan for the Department which was followed by a revised plan, identical except for the specific names of the research groups in the Department. In the assessors' report, they particularly refer to the old names. The changes are not too significant but we offer them for the record, and because we have now formalized these groupings in our operation:

Preliminary Submission	Corrected Name
Communications and Computers	Communications Engineering
Modelling and Design	Simulation, Optimization & Control
Materials/Devices	Materials and Devices
Medical Electronics	Medical Electronics

4. We completely agree with the assessors' recommendation that the Medical Electronics group should only develop in conjunction with the Health Sciences faculty at McMaster University. In the past, the program in this area has been carried out in cooperation with doctors in the Chedoke-McMaster Clinic. This has proved to be a valuable association which we intend to expand through the well-organized Hamilton District Health Council, of which the McMaster Health Sciences group is part.

We are in the process of hiring a new faculty member who will be a joint member of the Medical School faculty and the Department of Electrical Engineering. We feel he will be instrumental in helping us expand this program.

5. With regard to part-time students, we wish to confirm the surmise (page A-40) that our part-time enrolment is composed entirely of students who have completed all requirements but the dissertation. No Ph.D. program at McMaster can be taken on a part-time basis throughout, although we have recently instituted a half-time enrolment plan for candidates who do not have full-time employment elsewhere, and who must also put in one year of full-time residence.

ELECTRICAL ENGINEERING RESEARCH SPACE

Engineering Building

Room #		Area
216		588
215		1173
211		497
305		1491
233		1097
210		1020
109		200
109C		281
321		66
	TOTAL	6413

Senior Sciences Building (includes space assigned departmentally to Engineering Physics, but which is used for Electrical Engineering research):

Room #		Area
139		830
143		352
137A		544
140		420
	TOTAL	2146
	TOTAL NASF	8559

SUMMARY OF GRANTS

1972/73

Research Group	Assessors' Report	Revised Amount
Communications Engineering (CE)	$ 59,040	$199,479
Simulation, Optimization & Control (SOC)	27,000	27,000
Materials and Devices (M/D)	141,800	141,800
Medical Electronics (ME)	---	9,500
Power (P)	3,800	3,800
	$231,640	$381,579

C-16

UNIVERSITÉ D'OTTAWA
550, RUE CUMBERLAND

UNIVERSITY OF OTTAWA
550 CUMBERLAND STREET

OTTAWA, ONTARIO
Canada K1N 6N5

CABINET DU RECTEUR

OFFICE OF THE RECTOR

November 22, 1973

Dr. M.A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Ontario Council on Graduate Studies,
Council of Ontario Universities,
102 Bloor Street West,
TORONTO, Ontario. M5S 1M8.

Dear Dr. Preston,

This is a reply to your request for the University's comments on the A.C.A.P. consultants' report on doctoral programs in Electrical Engineering in Ontario.

We have noted with satisfaction that "except for the systems area, the eight departments have strength such that there is a reasonable overall balance without either excessive overlap or duplication" (page A-55). We note also that, based on a very comprehensive survey of the supply and demand for doctorates in Electrical Engineering presented in Chapter 1, it is recommended that no limit or quota be imposed for this discipline (Recommendation 1), and that "Attempts either to modestly increase or decrease this total are not likely to result in any major economic savings or expenditures within the universities" (page A-30).

Unfortunately, we find some aspects of the report rather subjective, and comments related to individual institutions vary to some extent in tone even when referring to items of evaluation in which two universities appear similar in terms of the data presented. One such example applies to the proportion of foreign students in each program. Thus, for two institutions, the following comment can be found: "There are not as many Canadian students in the program as the faculty would like. However, in this connection, McMaster is not in a worse position than other Ontario universities except for the University of Toronto" (page A-88). In the case of Waterloo one reads: "The faculty would like to enroll more Canadian students in their program, but accept students from outside of Canada to fill the ranks" (page A-106).

On the other hand, for Ottawa, the consultants state that: "A relatively high percentage of the students working for Ph.D. are of foreign origin" (page A-92). However, the data of figure 4.3, page A-39, show that all three institutions have a similar proportion of foreign students in their Ph.D. program. Other such examples can be found in the report, and it is our impression that they tend to show the program at Ottawa in a worse light than it deserves.

The University of Ottawa recognizes the validity of some of the comments expressed by the consultants with regard to its Ph.D. program in Electrical Engineering. We have noted also that the consultants have stated that "there is a sincere effort by the present chairman of the Department to rectify the situation", and that "there are some indications of improvements" (page A-94).

More specifically, we cannot agree with stipulations (i) and (iv) of Recommendation 5 which would not allow the Department to admit new Ph.D. candidates for a period of five years. If implemented, this recommendation would seriously affect the recruiting efforts of the Department which is hoping to attract at least two more staff members with demonstrated research ability. The consultants have noted that already the Department "has some outstanding faculty members" (page A-93). We feel that we can operate a Ph.D. program meeting all the criteria of quality set out by the consultants, and that the main area of difficulty lies in the structure and administration of the program, a problem to which the chairman of the Department is presently applying considerable effort. With regard to the admission of students, the Department has this year attracted five Canadian students at the Master level with graduate scholarships, including one 1967 Science Scholar. Any curtailment of admission of new Ph.D. candidates could seriously hamper the efforts at reorganisation and regrouping being carried out by the Department, and would surely deter the candidacy of excellent applicants at the Master level. We are not without knowing that these would be necessary corollaries of such a decision.

What we would want to propose to A.C.A.P.'s consideration is that our Ph.D. program continue, but in a modified and reduced form. The Department is convinced that it can, in a very short period of time, by limiting its program to two fields where it presently has strength, maintain a valuable specialized Ph.D. program. These two fields, to use the terminology of the consultants with regard to "Emerging Fields", can be described simply as Digital Communication Systems, and Large-scale Systems. We feel that such limitation of our efforts to these two fields of specialization would place our program in a position similar to that which the consultants regard favorably at Windsor (page A-114) and recommend for Queen's (pages A-97 and A-98). Furthermore, limitation of our Ph.D. program to the specializations mentioned would be consistent with the overall A.C.A.P. principle that there is room in Ontario for a number of small enrolment graduate programs in specialized fields.

One aspect of the program at the University of Ottawa which has not been given the consideration it deserves by the consultants is that it is set in a bilingual and bicultural atmosphere, and is the only electrical engineering graduate program in Ontario where the student can carry out his research and write his thesis either in French or in English. Furthermore, it offers our students, both anglophones and francophones, daily contact with both our official languages and national cultures. This is a particular asset for Ph.D. candidates who have recently immigrated to and established their home in Canada. For the Franco-Ontarian wishing to pursue graduate studies, the environment of the University of Ottawa is surely more attractive.

These are additional reasons why we request that A.C.A.P. recommend that our Ph.D. program in Electrical Engineering continue in the form proposed in this letter, which represents in effect a modification of our Five-Year Plan: the fields of research have been reduced from three to two closely related areas in which, moreover, our Department interacts with local industry (see page A-92).

A brief comment on Recommendation 5 (ii) is also in order. We do not consider this recommendation entirely workable, but we note that some of our professors are considered "qualified to guide doctoral research".
The investigation of areas of possible co-operation between the two universities has been going on for some time, particularly between our Department of Electrical Engineering and Carleton's Systems Engineering Division and Electronics and Materials Engineering Division.
This will continue, and we hope shortly to develop appropriate mechanisms for co-operation. With regard to Recommendation 5 (iii), better use is gradually being made in the Electrical Engineering departments of both universities of the possibility of exchange of credits for graduate courses taken at the other institution.

We recognize the usefulness of the suggestion expressed in Recommendation 2, and take note of recommendation 3, although we do not agree with the wholesale condemnation of admission standards implied in this recommendation. Similarly, we endorse the value of Recommendation 9, but question the validity of the suggestion implied in Recommendation 10 that admission policies and support practice may be contrary to the intent of Canadian immigration policies.

Yours sincerely,

Roger Guindon

Roger Guindon, O.M.I.,
Rector.

copy: Dr. Paul Hagen
Dr. Antoine D'Iorio

QUEEN'S UNIVERSITY AT KINGSTON

RESPONSE

to the

"Report on Doctoral Programs in Electrical Engineering in Ontario Universities"

September, 1973

Submitted to the
Advisory Committee on Academic Planning
Ontario Council on Graduate Studies
Council of Ontario Universities

November 28, 1973

General

The "Report on Doctoral Programs in Electrical Engineering in Ontario Universities" by the ACAP consultants (M.P. Bachynski, A.D. Moore, and M.E. Van Valkenburg) is a comprehensive document. We welcome it as the first assessment of its kind that has been attempted. We expect it to be especially welcomed by those universities whose departments of Electrical Engineering have been commended or encouraged or both. Less enthusiasm can be expected from those institutions where drastic action in the form of programme curtailment has been proposed.

Response to the Recommendations

Queen's University accepts, with some minor reservations, those recommendations (Nos. 1, 2, 3, 9 and 10) that pertain to all universities in Ontario and the Electrical Engineering discipline group.

Recommendation Number 6, pertaining to Queen's University, is accepted in part.

Our concentration at the doctoral level at present is in "communications" and "systems" and we would not expect this concentration to change soon and substantially. We are not prepared to accept "concentration" in these specified areas as implying cessation of activity in our other two selected areas of specialization.

Our doctoral enrolment is not expected to exceed the figures projected in our report "Study at the Doctoral Level" of January 25, 1973. The possibility of modest enrolment increase does exist - subject to the supply of capable candidates and the demand for their services after graduation, to the maintenance of admission standards, and the constraints on graduate student support in the form of awards and earnings. We see no reason to preclude such modest increase.

We approve the recommendation that our facilities be improved, and note that the proposal that we seek "negotiated grant" or similar major funding coincides with our own stated intent of January 25, 1973. However, we do not fully accept the consultants' statements in the body of the report on the adequacy of our facilities.

The recommendation that we seek more active involvement with government and industry is accepted. This objective is constantly before us. We do not accept, however, the arguments leading to this recommendation - namely that our present level of involvement is low and that we are in a position of geographic isolation. The reasons for the reservations set forth here will be further documented in what follows.

Response to the Report

The study of supply and demand for Ph. D. graduates in Electrical Engineering, together with the more subjective assessment of need, leads to a degree of optimism not shared for Engineering Ph. D.'s in general by Thompson and Lapp in their July, 1973, report for the Canadian Engineering Manpower Council on "Supply and Demand for Engineering Manpower Doctorates in Canada". Whether the optimistic assessment of demand is justified will remain to be seen. We hope the optimism is well founded; find some difficulty reconciling this optimism with the drastic measures suggested for two of the eight universities; and note the seeming inconsistency between these recommendations and the statement (p. A-17) that "it is unfortunate that such gross estimates, uncertain as they are, often are given great quantitative significance in arriving at major policy decisions."

We congratulate the consultants on their perception of the fact that the demand for engineering science doctorates more often than not means a demand for doctorates in the electrical/electronics area, and the correlated fact that "a large portion of engineering science baccalaureates take their doctorates in electrical engineering".

In the consideration of factors relating to the doctoral program we find a succinct assessment of size criteria, the need for relevance, the need to integrate graduate and undergraduate work, the role of foreign students, and the need for high standards as a means of achieving excellence. There is much conventional wisdom in this section, and with most of it we tend to agree. While we may have some skepticism about the somewhat dogmatic belief that "critical size" is a really essential factor in achieving high quality (this belief is by no means universally accepted) we are not strongly disposed to be contentious on this point because we believe we have this size in the areas we have chosen for ourselves at Queen's.

In the evaluation of doctoral programs in Ontario we find ourselves coming into areas where we have less cause for satisfaction with the report - not merely because the authors have some uncomplimentary things to say about Queen's (no university really escapes untouched) - but because there is cause for concern about the method of evaluation. There are two main points to be made.

1. The arbitrary specification by the consultants of seven "research fields". This fragmentation of Electrical Engineering was resisted from the outset by the discipline group. (See letter from the Discipline Group Chairman to Professor M.A. Preston dated May 31, 1972.) The areas chosen in some cases do not provide a neat or beneficial correspondence with those areas specified by Queen's, and our ratings have suffered on this account. We believe it indefensible to eliminate "electronics" as a research field while admitting the subfield of "biomedical electronics", and other fields just as broad as electronics, such as "systems", "power" and "communications".

We note particularly the statement by the consultants: "This rather arbitrary decomposition of doctoral programs has been made in order to be able to quantify some of the data concerning faculty interests, research funding, and doctoral enrolment. Because the information was not all uniformly clear, it has been necessary for us to draw inferences from some of the data that may not be totally justified." (Underlining ours.) It is difficult for us to accept some of the inferences drawn - particularly in Table 4.9 (page A-61) - and the possible impact of the exposure of these inferences, unless they can be defended as totally justified.

2. A few of the conclusions - in the chapter on evaluation as well as in the appendices on the institutions - seem to be based on 1972-73 data only when data for a longer period were available and could have been used. We are particularly concerned about the inferences drawn from Fig. 4.3 on the immigration status of doctoral students. These data are used as a basis for very derogatory comments about Queen's that we feel are quite unjustified, particularly because very favourable comments are made, on the basis of evidence essentially no different, about some of our sister universities.

The evaluation for Queen's University gives us less cause for satisfaction than we believe is justified by the facts. Some quantitative basis for our concern was put before the consultants when their draft report became available, and some minor changes were made by them. The changes have not been sufficient however to remove our conviction that elements of subjective and negative judgement, not supported by the facts, have crept into the quantitative ratings pertinent to Queen's and the qualitative statements in some parts of the Appendix on Queen's (pp. A- 95 to A- 98). Some details will be set forth in what follows.

Consultants' Comments on the Program at Queen's University

1. Assessment

In Section 4.5 of the report - from page A-59 to page A-62 - the consultants sum up their views of the eight institutions. Their assessment depends very heavily on the arbitrary selection of seven fields to represent all of electrical engineering - and electronics is not one of these. We note the recognition of this field by such noteworthy institutions as M.I.T. (Research Laboratory of Electronics). We note the recognition in the name of the Institute of Electrical and Electronics Engineers.

We have already noted the stated opposition of the Electrical Engineering discipline group of other engineering discipline groups to assessment on the basis of a set of subfields or research areas. In consequence of this we find arbitrary decomposition of our departmental data that is not in our interests, and in some cases incomprehensible to us. For example, a staff member whose field was clearly (from his curriculum vitae) a well-documented specialist in devices and materials, and whom we would class as a member of our Electronics Group, must have been otherwise classified by the consultants. Yet there is no basis for any other such classification. We find a doctoral student, but no staff and no research funding, associated by the consultants with biomedical electronics. Again this matter is within the purview of our Electronics Group. There has been substantial funding for the work in which the student is engaged. There is substantial support from and liaison with the University's Biomedical Engineering Unit in the Faculty of Medicine and with the Department of Psychology. Nevertheless, while a problem in biomedical electronics, or other problems in the biomedical area, may engage the attention of members of our staff from time to time, we have seen no reason to develop this as a field apart from the main stream of electronics when there is such dominant strength in this area at the University of Toronto.

With respect to the rating (B+) in Communications on page A-61 (Table 4.9) we find it difficult to reconcile this with the staffing, doctoral population, research funding and laboratory facility ratings set forth in Tables 4.5, 4.6, 4.7 and 4.8 - especially as it relates to those institutions that have been accorded higher and/or equal ratings. There seems to be little basis in fact for the conclusion reached by the consultants. We would not by preference compare ourselves with other universities. But the report does; it does so to our disadvantage; and we believe it does so unfairly. Accordingly, we suggest for comparison the following table, based on the consultants' data. The numbers indicate rank - in number of staff, number of students, research funding (all in 1972-73), and quality of laboratory facilities.

Table	Carleton	McMaster	Queen's	Toronto	Waterloo
4.5 - Staff	5	4	2	3	1
4.6 - Students	1	2	3	4	5
4.7 - Funding	2	3	1	6	5
4.8 - Laboratory Facilities	1	3	4	4	2
Average Rank	2.25	3	2.5	4.25	3.25

We do not necessarily believe in this table, but it would seem to be at least as objective a way of drawing the conclusions shown in Table 4.9 (page A-61) on "Capability of Giving the Ph. D." (in Communications) as any that has been stated.

Continuing with this theme, we find ourselves credited with faculty but no students and no funding in the "computer" field. Our facilities are classed at the B level and a "nil" capability rating is assigned. We would not have invited rating in this field but have been given one. In "devices and materials" we are shown with no staff, no students and no funding (all demonstrably false data), class B facilities, and a B capability rating. Again we would not have invited rating in this area. The situation is similar in electromagnetics.

In the "power" area we agree with the allocation of staff and probably with the assessment of facilities. The funding (and any supplementary reports that we have provided on funding) does not include the substantial sums ($16,000 in 1973-74) that are at the disposal of staff members in this area for work supported indirectly, through the Department of Physics (Professor Atherton) by sponsors associated with the Canadian Institute of Guided Ground Transport. This is interdisciplinary work of high order, and we find it difficult to accept the view or to acknowledge the credibility of the suggestion (page A- 97 and A- 98) that "it is doubtful that it (the department) should offer programs in Energy Processing ..." when at the same time Windsor - seemingly comparable by most objective measures, and a school that has concentrated recently in the power field - is said to have "strengths not apparent at other institutions".

For the most part we reject the allocation, as determined by the consultants, of faculty, doctoral students and research funding to the seven fields. This allocation is inaccurate and misleading, and we are at a loss to know how it was devised. We could possibly offer corrected figures, but this could be construed as acceptance of the fragmented view of electrical engineering established by the consultants. We reject this fragmented view.

2. Student Body and Admissions

We are generally in agreement with the recommendation that Queen's (and other Ontario universities) should examine closely and endeavour to raise its effective admission standards. While maintaining minimum standards all institutions usually seek to raise their effective admission standards. We take exception however to the statement (on page A-96) that Queen's "has had average success in attracting the better graduate students". The only objective evidence on this subject is set forth in the report in Fig. 4.6 on page A- 44. Queen's is shown to rank third among the eight institutions in the percentage of its full-time students who have held major scholarships in the five-year interval from 1968 to 1972. In response to earlier reaction the consultants have changed their wording from "only average" to "average". Clearly the record would justify "better than average". We cite this as one of several examples in which the choice of words and the subjective impression created by them is indicative of negative bias inadequately supported by the quantitative evidence.

On the matter of immigration status of our doctoral students we find cause for concern also. We would be less disturbed if the consultants were uniform in their criticisms as between institutions where the documentary evidence is similar. They are not however. The bar graphs of Fig. 4.3 on page A-39 (immigration status) and Fig. 4.6 on page A-44 (sources of support) indicate for example that objectivity would require similar negative comments about some other institutions. Instead we find for example, for two institutions with comparable Canadian population and comparable numbers of major scholarship winners, the following comments.

re Queen's Department	re Comparable Department
"...average success in attracting the better graduate students" (page A-96)	"...good student body..." (page A-89)
"...it is noticeable that they (Canadians) form a definite minority..." (page A- 97)	"...no reason to question the high quality of the students..." (page A- 88
"...high rate of disappearance of Canadian students..." (page A- 98)	"...good students do enter the program from Canada..." (page A-88

In the face of the quantitative data presented in the report this apparent lack of objectivity is difficult to comprehend.

The full version of one of the statements above is (page A- 98): "There appears to be a high rate of disappearance of Canadian students between the Master's and doctoral stages". We find this statement difficult to accept for the following reasons:

(a) No documentary evidence is provided to indicate the suggested "high rate of disappearance".

(b) Whatever rate of disappearance may exist,we question whether it differs appreciably from that for other departments of Electrical Engineering in Ontario which have not drawn similar negative comments.

The consultants have made no comment whatever upon the fact that Queen's requires, for admission to the Graduate School, documentary evidence, in the form of a satisfactory TOEFL score (Princeton) or a satisfactory standing on the Michigan English Language

Test. The standard is high enough that we regularly lose some good foreign graduate students to other Electrical Engineering departments in Ontario that do not require such a test. The institutions that have accepted these applicants are among those for which the consultants have praise and no criticism of admission standards.

Other cases can be documented in which admission on purely academic grounds has been refused at Queen's and subsequently granted at other Ontario universities that have been given higher "capability" ratings by the consultants.

3. Geographic Location

On page A- 97 of the report the consultants state that "the University does not have the advantage of being ideally located with respect to industry or to government laboratories as some others do. Evidence of this isolation was apparent". We accept neither of these statements. The consultants cite none of the evidence said to be apparent. Their judgement on this matter is a subjective one, and we regard it as biased. The evidence as we see it is as follows.

(a) Queen's is centrally located with respect to the three major centres in Canada of activity in the electrical and electronics field and there is easy and convenient access to all three. At the same time we experience none of the disadvantages associated with location in a large metropolitan centre.

(b) The Department of Electrical Engineering has had and continues to have strong interaction, including substantial contract research commitments ($57,471 in 1972-73) with the Department of Communications and its Communications Research Centre (CRC) in Ottawa. The record of interaction and cooperation stretches back in time to the era when CRC was the Defence Research Telecommunications Establishment. Biennial symposia on communications have been co-sponsored with this organization at Queen's over a period of twelve years. These symposia have been national in scope and have contributed substantially to the recognition and development of communications research in Canada.

(c) The Department has significant interaction with a number of major industries. We cite as evidence the sources of our research funding. Data supplied on request to the consultants by the Department of Electrical Engineering in a report entitled "Supplementary Information for ACAP Ph.D. Program Assessment", dated August 15, 1973, indicated that the department's research funding for the 1972-73 year was $240,508. The sources of this support were set forth. They included direct funding to departmental staff from the Canadian Institute of Guided Ground Transport (the financial support of which comes mainly from industry), Falconbridge Nickel Mines, International Business Machines, and Bell Canada. Indirect support through the Department of Physics related to the Magnetic Levitation project was not included. Total funding from these industrial sources was $79,093. In percentage terms this means that some 30.9% of total funding was from sources that are essentially industrial. Objective comparison of these figures is invited, as a measure of industrial interaction, with similar data, if it is available, from other departments of Electrical Engineering.

There are other forms of interaction, including the presentation of seminars, exchange visits and consulting activity, that the consultants seem to have ignored. We regard their comments as biased and unfounded.

4. Physical Facilities

We note with satisfaction the consultants' comments that the "departmental facilities are well suited to undergraduate instruction", but we do not feel that this is particularly pertinent to the matter at hand. We find it difficult to accept the derogatory comments that follow - "facilities... inadequate for graduate and faculty research on any scale"; "a lack of major experimental apparatus"; "equipment lists are not impressive". We make the following points, drawn from consideration of our activities, our equipment, our submitted equipment lists, and the submitted equipment lists from other departments of Electrical Engineering. (There lists are not included in the report, but were available to the consultants.)

(a) Graduate and faculty research is proceeding on a considerable scale. Not all of it is experimental, but the balance between theoretical and experimental work is quite defensible. The production of theses and published papers - based on work at Queen's - supports this statement (the graphs of Figure 4.9 - page A-53 - notwithstanding, because these graphs in some cases reflect a history of activity at institutions other than the ones being assessed). It would have been more pertinent for the consultants to comment on whether the experimental facilities were adequate for the programs under way.

(b) Our submitted list of major facilities and equipment was extremely succinct. In no case did we list any item of less than the $5,000 value specified (as some other institutions clearly have done). In no case did we list assemblies of smaller items which, taken together, constitute a major item. In short, the list is lean, not padded.

(c) Our list of extradepartmental facilities is similarly succinct. In listing the major central computing facilities available we did not see fit to break each of two major computer installations down in such a way as to describe all ancillary facilities, input-output devices and the like. Some others have done this and apparently, by doing so, have impressed the consultants. No elaboration of our own extradepartmental facilities was requested. In this case also we believe that we are, in effect, being criticized for failing to produce a well-padded list.

(d) After contemplation of the equipment lists submitted by some of the other universities - in many cases with dollar values cited - and comparing total dollar value with the output of doctoral graduates we are inclined to question ourselves, and to wonder why the consultants have not questioned, the cost effectiveness, in terms of equipment, of some programs that have been praised. For example, in one case major departmental equipment is listed to a total of nearly $500,000. In the interval from 1968-73 six Ph. D. 's were graduated. In another case nearly $300,000 in departmental equipment corresponds to the graduation of five Ph. D. 's.

5. <u>Seminars</u>

The consultants note (on page A- 96) that "There does not appear to be required participation in regular seminars (by graduate students)". Earlier reference is made to this subject (on page A-35). The consultants note in this instance that "The (seminar) requirements range from none at all at Queen's to a very structured program at Windsor." Lest these comments imply criticism we point out:

(a) that the level of graduate seminar activity is very high, and can be documented, even though there is no formal requirement for seminar presentations by doctoral candidates.

(b) that initiatives have been taken to promote seminars having broad departmental interest, that the four departmental technical groups have conducted seminars on more specialized topics, and that graduate students themselves have taken initiative in some cases in conducting seminars.

(c) that all doctoral candidates are required to submit to an oral comprehensive examination in their area of specialization (as noted by the consultants on page A- 96).

Conclusion

We note that much of what the consultants have to say about Queen's University is factual, and that some of it is complimentary. With this we are naturally pleased and feel that we have no cause to comment at great length on these aspects of the report. We are concerned however about certain isolated statements and points of view which seem to us to be inadequately based upon fact. We believe they may be detrimental to the well-being of our doctoral program. These statements, having been made, cannot be recalled, and we have felt constrained to challenge and refute them in this response.

The Advisory Committee on Academic Planning has, in some instances, shown itself prone to make recommendations which we believe to be more detrimental to the long term interests of students wishing to pursue doctoral studies in Ontario than even those suggested by the Committee's consultants. In this instance the consultants, though taking an optimistic view of the demand for Electrical Engineering doctorates, have recommended the actual or virtual termination of two programs that are acknowledged to have features of high quality. We do not believe, in the light of the evidence given in the report, that these recommendations should be implemented, let alone any of a more drastic nature. The discipline group has pointed out the relatively short history of doctoral work in Electrical Engineering in Ontario, and the record of achievement to date. It has recommended against undue perturbation of the system in view of the modest nature of the various departmental plans for the next five years. We concur with this point of view.

QUEEN'S UNIVERSITY
KINGSTON, ONTARIO
SCHOOL OF GRADUATE STUDIES AND RESEARCH

December 7, 1973

Dr. M. A. Preston
Executive Vice-Chairman
Advisory Committee on Academic Planning
Council of Ontario Universities
102 Bloor Street West
Toronto, Ontario M5S 1M8

Dear ~~Dr. Preston~~:

You have kindly brought to my attention the view that the document "Response to the Report on Doctoral Programs in Electrical Engineering in Ontario Universities" submitted through me may not constitute a considered University response.

The response was prepared in the first instance by the Head of the Department of Electrical Engineering after thorough consultation with his colleagues. Thereafter it was examined by the Dean of Applied Science, Dr. Uffen, and by myself. Dr. Uffen and I agreed that a careful analysis of the Consultants' report in relation to Queen's activities in the field had been prepared and that the points made in rebuttal were worthy of serious consideration before ACAP prepares its report.

Our support of the paragraph entitled "Conclusion" was and remains less unequivocal. However, the comments made in that paragraph are related to the general theme of the response and should be read in that context since the value of the assessment exercises is undergoing experimental test. There are bound to be differences of view concerning the benefits of a complex study of this nature. There is merit in the preliminary stages of the reporting and the responses to allow reactions within particular disciplines to be fully and frankly expressed. Dr. Uffen and I therefore considered that the response should go forward without substantial alteration.

I think that it is also worthwhile to report that we have only begun to develop procedures within our University which will allow more exhaustive and widespread examination of consultants' reports and those prepared by ACAP within the comparatively short period available for the preparation of comments. I am hopeful that our University will have achieved this aim by the time that further reports from ACAP are received and that we shall then be able to render fully considered comments which will accurately represent the University's views. Bearing this in mind and the value of individual viewpoints, I believe that the response dealing with electrical engineering may be regarded as a preliminary indication of Queen's views which may be somewhat altered when the ACAP reports on the engineering disciplines are examined as a group.

Should you believe that this note helps to clarify the Queen's response, please append it to the document already provided.

Yours sincerely,

R. McIntosh
Dean
School of Graduate Studies and Research

RM/mb

c.c. Dean R. J. Uffen

UNIVERSITY OF TORONTO

School of Graduate Studies

OFFICE OF THE DEAN

Toronto 5, Canada

November 13th, 1973.

Dr. M. A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Council of Ontario Universities,
102 Bloor Street West, 3rd Floor,
Toronto, Ontario. M5S 1M8.

Dear Dr. Preston,

The University of Toronto congratulates the consultants for the Electrical Engineering assessment on the quality of the report they have presented to ACAP. The report is well-researched, well-documented and provides the guidance needed by the Universities for planning in the next five years. In many ways it might serve as a model for other consulting groups.

Once again, we are presented with data on manpower needs that contradict earlier projections, particularly those supplied in the Canadian Engineering Manpower Council Report of July, 1973. In Electrical Engineering, as we have also noted in other engineering disciplines, there is no problem of oversupply of Ph.D's, as suggested in the CEMC document, but indeed a strong possibility of undersupply. We can only regret the individual and social costs which result from policies based too closely on projections subject to such errors.

The recommendations (A-ii and Aiii and A-63 to A-65):

1. We agree.

2. This recommendation is acceptable to the department and to the University. We suggest that consultation concerning on-going research and development activity and need be considered as an activity for other discipline groups.

3. We agree in principle with this recommendation, though we would make the following points:

   (i) It seems overly rigorous to demand "proven" research ability before admission to the Ph.D. We suggest "potential research ability" or "clear research capability" or a similar phrase.

   (iii) Corrective action has been taken to resolve the problem noted on p. A-101 concerning departmental examination policies.

   (iv) The department has in recent years reduced the average time taken from the Master's degree to complete the Ph.D., and intends to reduce the time still further.

Dr. M. A. Preston November 13th, 1973.

4. In proceeding with the implementation of the five-year plan submitted by the departmeut, we acknowledge the problems noted by the consultants on p. A-46 concerning the lack of contact between research groups, though it should be noted that each group contains on an average six staff members and thirty graduate students. The department will nonetheless attempt to find mechanisms for promoting activities which involve the whole department. The isolation of some groups has resulted from the housing of the department in four buildings and is an example of the harm that can be caused to graduate programs by the restriction on capital funds for new building.

On p. A-102, the consultants have quoted a general rule of the University's School of Graduate Studies for admission. The Department of Electrical Engineering requires first-class standing in the Master's degree for admission to the Ph.D., and well above a standing of B for admission to the Master's programs.

9. We agree with this recommendation which is related to recommendation 2.

We have appended to this letter a list of corrigenda submitted to us by the Department of Electrical Engineering.

Again we would suggest that ACAP consultants be provided with reports from earlier assessments. The Electrical Engineering report would be a helpful model for the consulting group in any discipline.

Yours sincerely,

A. E. Safarian

A. E. Safarian,
Dean.

BSM/jd

UNIVERSITY OF TORONTO: ACAP REPORT ON ELECTRICAL ENGINEERING: CORRIGENDA.

Some of the figures for Toronto on page A-58 are rather inaccurate. The following figures represent better estimates of the research support in the fields listed:

Communications	58.6
Computers	176.3*
Devices and Materials	53.4
Electromagnetics	129.8
Power	170.3
Systems	67.7

* Includes 119 thousand negotiated development grant.

A small part of the error seems to have been caused by the omission of the names of two staff members from the lists of staff in the various groups that were sent to ACAP. Would you please alter the following numbers on the "Toronto" line on page A-56 to take this into account:

Computers	6.6	(instead of 5.6)
Power	10.1	(instead of 9.1)

It should be noted that the rows of totals at the bottoms of the charts on pages A-56 and A-58 would also need to be altered. These have not been re-computed because there might be other changes made in the chart too, and these would have to be taken into account.

On page A-100, the 7th line from the top should be changed to say that 12 of the 14 full professors have major grants (average value about $22,000).

Response of the University of Waterloo to the Report of the Electrical Engineering Consultants to the Advisory Committee on Academic Planning submitted to ACAP, November 14th, 1973

The University of Waterloo congratulates the Electrical Engineering consultants for the excellent report which they have presented. This report is one of the best that we have read and will be very useful to the individual universities and to the university system in planning doctoral work in electrical engineering. In this submission, we will make a few general comments on the report and some specific comments on those aspects of it that refer to the programme at the University of Waterloo.

General Comments:

Chapter 2 of the report presents a very careful survey of the supply and demand problem for doctoral graduates in electrical engineering. This survey is much more likely to be a reliable basis for planning than is the survey of Thompson and Lapp presented to the Canadian Engineering Manpower Council. In particular, we fully support the main conclusion of this section stated on Page A-19 that "the demand and supply of electrical engineers at the doctorate level in the next five-year period will be approximately in balance.". Since the supply is based upon the planned enrolments of the universities, it is clear that these enrolment levels will come close to providing an adequate number of Ph.D.'s to meet the anticipated demand. There would appear, therefore, to be no basis for recommending that the total doctoral enrolment in electrical engineering in the Ontario system be curtailed.

In Section 2.7, the consultants discuss the question of need. They point out that "any underproduction of graduates in this field could have significant social consequences and could result in Canada not being able to achieve its goals". On the other hand, an overproduction of graduates would have less serious consequences and could even lead to beneficial results by forcing an upgrading of certain positions and the development of more entrepreneural activities. The University of Waterloo fully supports this position.

In Chapter 3, the consultants discuss a number of factors which they consider to be important in relation to doctoral programmes in electrical engineering. We agree in general with the statements in this chapter. We wish to support in particular the consultants' call for a greater emphasis on quality rather than quantity. We also support the consultants' contention that for a doctoral programme to be viable, it must achieve a minimum critical size in the range of 10 to 20 faculty members and 10 to 20 graduate students.

Specific Comments:

We turn now to specific comments in the report which refer to the programme at this university. On Page A-36, under subsection (g), the consultants refer to the fact that the University of Waterloo is the only university in the province which has no formal course requirements for the Ph.D. This statement should not be taken to imply that our Ph.D. students do not as a rule take any courses. A fuller explanation of this point is given by the consultants in Appendix 3 on Page A-106 where they present a fair description of the actual situation. We need only add that the question of formal course requirements for doctoral work is currently under review in the Faculty of Engineering.

On Page A-40, the consultants comment on the large non-Canadian component in the graduate student population at Waterloo. This is a problem which the university has recognized for some time. It is a problem that is not unique to electrical engineering but applies to all of the other engineering disciplines as well. The university has done everything it can to encourage Canadian students to go on to graduate work when they have the academic qualifications to do so. There is probably no single reason why so few Canadian students choose to go on to graduate work in engineering. One important factor in our view, however, is the impression which many young Canadian engineers have that job opportunities for Ph.D.'s are very limited, particularly in Canadian industry. The employment experience of our recent Ph.D. graduates in electrical engineering does not support this impression. Some Canadian industrial R & D laboratories have to import Ph.D.'s because there are not enough Canadian graduates available.

Another factor which discourages Canadian students is the low rate of remuneration for graduate students. This factor is particularly important at

Waterloo where because of the cooperative undergraduate programme, the vast majority of our baccalaureate students have good job offers before they graduate.

The most serious criticism of the programme at Waterloo relates to the time taken by our students to complete their Ph.D. This is a problem which the university has been aware of and is taking steps to correct. Of the five Ph.D.'s in Electrical Engineering who graduated at the recent Fall Convocation in October 1973, three had spent sixty months or less from their Bachelor's degree which is about the average length of time across the province. Two of the five graduates had spent an unacceptably long time in their programme but one of these had had a rather lengthy illness during this period.

On Page A-46, the consultants comment on the insularity of research groups at Waterloo. This is another problem which the university has recognized and steps have already been taken to increase the interaction among students in the various groups and to break down the type of insularity which the consultants refer to. We agree completely with the consultants' statement that "today's graduate needs flexibility" and that this requires "a critical balance between breadth and depth in the doctoral programme".

In Table 4.8, the consultants indicate that there is no graduate work in the biomedical field at the University of Waterloo. This is not correct since there is one full professor in the department, Dr. L. Y. Wei, whose work in the study of nerve conduction has achieved international recognition. Dr. Wei has also received significant research grant support for his work from NRC and DRB and has supervised a number of doctoral students. The consultants themselves refer to Professor Wei's work in Appendix 3 in the section devoted to the University of Waterloo. As stated in the report, this is a small activity and one which the university does not intend to increase but it is nevertheless of high quality and should be recognized.

Finally, we would like to comment on the projected enrolment levels for the University of Waterloo. The university's official plan which was submitted to ACAP with the documentation for the assessment, projected a constant enrolment for doctoral students in electrical engineering over the next five-year period consisting of 20 full-time students and 2 part-time students. We now view this projection as being somewhat conservative. The current enrolment for the year 1973/74 is 25 full-time students and 5 part-time students. It now appears to us to be reasonable to expect the department's enrolment to grow over the next five years to a level of 30 to 35 full-time students and about 5 to 10 part-time students. This growth is well within the capacity of the department as indicated by the consultants and is consistent with their recommendation that the stronger departments should plan for some modest growth.

Comments on the Recommendations:

The consultants make ten recommendations. The first three of these and the 9th and 10th are general recommendations applicable to all of the universities in the system. The University of Waterloo fully supports these recommendations.

Recommendation 4 concerns the University of Waterloo in particular and encourages us to carry out our five-year plans relating to graduate work in electrical engineering "including some modest increases in student enrolment where desired". We accept this recommendation and as we have indicated above, will plan for a Ph.D. enrolment increasing over the next five years from the present level of 25 full-time students and 5 part-time students to somewhere in the range of 30 to 35 full-time students and 5 to 10 part-time students.

The University of Western Ontario, London, Canada

Faculty of Graduate Studies
Office of the Dean

November 15, 1973

Professor M.A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Ontario Council on Graduate Studies,
Council of Ontario Universities,
102 Bloor Street West,
Toronto, Ontario.
M5S 1M8

Dear Professor Preston:

Re: Electrical Engineering

You will recall our recent conversation in Ottawa about how this University should approach the ACAP assessment of Electrical Engineering.

You had already been apprised of the fact that this University, from the time the degree was initiated, has offered the Ph.D. in Engineering Science and not in one or other of the Engineering specialties. The format assumed by the recent so-called "mini-assessment" which was strictly oriented into sharply defined subdisciplinary lines has generated reports which do less than justice to the rather substantial research and teaching effort proceeding in the Faculty of Engineering. This treatment is particularly exemplified in the report in what has been defined by the consultants as an appropriate program for electrical engineering. The faculty group that can be identified as being concerned about matters electrical had a number of activities which were acknowledged by the consultants but which were considered by them not to be within their definition of electrical engineering.

It would be our contention that we are not seeking to give Ph.D.'s in Electrical Engineering nor did we ever assert that we were. We are seeking to give a general degree in Engineering Science which, of course, must be focused for research purposes. The focus, however, is often at the area between subdisciplines which can be more easily approached by a small group which is not encumbered by departmental barriers.

We would protest that we were judged in the case of the Electrical assessment in a configuration which we did not seek to meet and in which we did not wish to be judged.

Professor M.A. Preston,
November 15, 1973

When we have had an opportunity to examine all of the specialty appraisals we shall seek to put our position in a comprehensive report. In the meantime, however, we would maintain that the criteria of assessment used in the Electrical Assessment were inappropriate to our operations and the analysis accordingly produces an irrelevant answer.

Yours sincerely,

H.B. Stewart,
Dean,
Faculty of Graduate Studies.

HBS/mmd
c.c.: Dr. R.J. Rossiter,
Dean A.I. Johnson,
Dr.J.E. Zajic,
Dr. I.I. Inculet,
Dr. R.G. Kidd.

A Response of the University of Western Ontario to the Advisory Committee on Academic Planning with respect to the Engineering Specialty Assessments (1973).

November 29, 1973

Historical Aspects

Approximately 20 years ago (1954) on the recommendation of the Faculty of Arts and Science the Senate of the University of Western Ontario established a Department of Engineering Science. This Department undertook to gather the faculty necessary to establish an independent Faculty of Engineering Science and Faculty status was granted to this group in 1960. The beginning of formal graduate study was the offering of an M.E.Sc. program which received the approval of the Faculty of Graduate Studies and Senate in 1961. The first candidates (4) were admitted in September 1962 and by 1964-65 the number of M.E.Sc. candidates had risen to 18. In October 1964 the Faculty of Graduate Studies approved the establishment of a Ph.D. program in Engineering Science and the Senate supported this action on January 29, 1965. From the outset an effort was made to emphasise the interdisciplinary nature of the program and graduate training was offered in a limited number of areas which at that time included chemical and biochemical engineering, soil mechanics, structural engineering and thermodynamics. Since its inception the Ph.D. program has produced a number of graduates

1969	-	1
1970	-	1
1971	-	6
1972	-	6
1973	-	6

In 1973-74 there were enrolled in the Ph.D. program 29 full-time students and 15 part-time students. All of these students have received or are enrolled in programs leading to a Ph.D. in Engineering Science and none of them has received a degree designated as serving one of the traditional specialties of engineering (e.g. chemical, mechanical, etc.).

The "Ring of Iron" published in 1970, among other things, recommended that the Faculty of Engineering Science drop the "Science" from its name (Ring of Iron, p. 77). The Faculty, after considering this matter, elected to retain this name as it did its interdisciplinary programs. The "Ring of Iron" did recognise the interdisciplinary nature of the programs by recommending that Western "concentrate" on environmental engineering which was acknowledged at that time to be a foretaste of the future. At that assessment it was also noted that "Western has gained distinction with its work in industrial aerodynamics, electrostatics and bioengineering". (Ring of Iron, p. 76).

Present Assessment

As a consequence of dissatisfaction with the stringency of Ph.D. recommendations in the "Ring of Iron" as adopted by the Council of Ontario Universities, the Council of Deans of Engineering has sought a reassessment of the Ph.D. programs in Ontario Engineering Schools. This task was undertaken under the aegis of the Advisory Committee on Academic Planning and something which has been erroneously termed a "mini-appraisal" has been performed.

The conditions under which this appraisal was undertaken are of particular interest because the form which this assessment has taken fails to take cognizance of work of an interdisciplinary nature which may be deemed to be outside the traditional specialties of civil, electrical, mechanical, chemical and metallurgical and materials sicence engineering. Examination of the five reports which have been received reveals rather remarkable differences between reports in spite of the fact that the consultants seem to have been given substantially equivalent instructions (with the possible exceptions of mechanical and chemical groups who do not specifically report their terms of reference). Remarkable perhaps are the prevalent comments about "critical size" when the printed terms of reference contain no mention of critical size.

As the present assessment has been conducted, it seeks to determine whether the engineering schools of the province contain five individually certifiable traditional specialties of engineering. If this was the objective of the assessment it was not so stated in advance. Not surprisingly, the large schools with substantial groups in each of the specialties survive assessments of this sort. The smaller schools regardless of the quality of their operations when judged in this particular frame of reference are found wanting in one or more of the traditional specialties. That is not to say that the discipline is not represented in the school since it must be to meet undergraduate instructional needs but the group practising the specialty is small and does not meet some arbitrarily defined critical size.

What can a school that is faced with this difficulty do? Aside from the obvious and in general unacceptable possibility of retiring from competition the researcher in the small "sub-critical" groups seeks to meet the need for interaction with other professionals and to develop his own intellectual pursuits by developing liasons with other individuals in related fields. The consequence is that individuals with different backgrounds, information and skills address themselves to problems which they have in common. At its best this kind of development can be the most exciting research conceivable. At its worst the products of the activity may be minimal or zero. However, we would contend that operations of this sort which stem from small interdisciplinary groups are potentially of great importance and furthermore, that the present assessments carried out along stereotyped lines may not detect these activities and are likely not suited to the evaluation of them.

It will be evident that interactions with individuals in other disciplinary specialties, however integral to the research in hand, will not permit the specialist group sparsely represented on staff to meet the criterion of critical size when the assessment is carried out in the framework of traditional disciplines.

The situations which prevail at Western in which these difficulties of assessment are most easily identifiable lie with the Electrical and Materials Science groups although the prevailing interdisciplinary attitude of faculty members in other groups leads to a reduction in the vertical integrity of the traditional specialties and to an enhancement of horizontal interactions between specialties. Encouragement of this horizontal interaction has been a conscious policy within the Faculty of Engineering Science and is a major determining factor in the decision of the Faculty to offer an Engineering Science program rather than programs in the traditional specialties.

The Engineering Science Concept

The absence of departmental structure and all that it contributes to specialty tribalism, the limited dimensions of the Faculty (approximately 43 F.T.E.), and the existence of congenial relations has led to development of extensive interaction and collaboration between groups within the Faculty. For similar reasons it has also been possible to develop interfaculty research activities in the biomedical area, (collaborative activities in both biomedical engineering and applied physiology), in radioscience (as participating members in the Centre for Radioscience) and in computer science (where the systems engineering group has developed a collaboration). The abiding interest of the Faculty in environmental matters has promoted interaction with other parts of the University which may be expected to bear fruit in the future. It should be noted that in all five of the assessment reports the comments on the quality of the work in hand were favorable.

In effect, circumstances have dictated that a particular course of development be followed. It would be our contention that this course has led to much that is valuable and worthy of development. While the route we pursue may be inappropriate to other Engineering Schools we would request that we be judged in this framework and not in the traditional format which cuts across rather than displays our most effective activities.

These remarks may be concluded by a statement that as recently as November 14, 1973 and with the full knowledge of the various consultants reports, the Faculty of Engineering Science reaffirmed its intent to continue to offer undergraduate, masters and doctoral training in Engineering Science and not in any of the specific sub-disciplines.

UNIVERSITY OF WINDSOR

RESPONSE TO THE ACAP CONSULTANTS

"Report on Doctoral Programs in

Electrical Engineering in Ontario Universities"

We have examined the ACAP Consultants report relating to Electrical Engineering Disciplines in Ontario Universities and would like to compliment the Assessors on their thorough evaluation of the Ph.D. programs and their excellent report.

We are particularly appreciative of the responsible manner in which the consultants have dealt with the quality assessment and have taken a firm stand against imposing "quotas" for engineering Ph.D. students upon Ontario Universities, but instead have recommended strongly a rigid control of admission standards and examination procedures in the endeavour of securing a high standard of excellence.

To ensure that these goals are achieved at large, the consultants make specific recommendations to be followed by all Electrical Departments in Ontario Universities (page A-65, section 9).

A further point in the report (p. A-78) which we strongly endorse is that "the committee supports the position that good doctoral work can proceed in small departments and large ones, provided that competent faculty members are involved, that high quality students are attracted and that high standards are ensured through University imposed regulations relating to examination procedures, etc."

The above points are in line with the philosophy of the Committee of Chairmen of Electrical Discipline of the Ontario University System and wete implicitly or explicitly stated in the Report submitted by the discipline group.

The specific recommendations in the report for the Ph.D. program in Electrical Engineering at Windsor are consistent with the plans submitted by our department and are also in line with the view expressed by the Electrical Discipline Group.

We see, however, no special reason to suggest that our program be subjected to a review after a five year period when time is not suggested for others. A periodical review of our program as well as those of achools could be beneficial and possible desirable, but such exercise should be undertaken by the discipline group. The discipline committee would serve as a regulatory body for the whole system. Once the concept of operating the Ontario Electrical Schools' graduate program as a system is accepted, the assessment of any part of the program in isolation would serve little purpose.

A P P E N D I X D

PROCEDURE OF PLANNING STUDY AND TERMS OF REFERENCE

Procedure for Electrical Engineering Planning Doctoral Assessment

conducted by ACAP in co-operation with CODE

1972-73

A. Tasks Requested from Discipline Group (with help available from ACAP at all stages)

A.1. Meet with representatives of ACAP and CODE and discuss the specialty fields assigned to this assessment. An initial meeting of the five engineering discipline groups may prove desirable. The field allocations may be altered by ACAP as a result of these discussions and CODE comment.

A.2. Suggest a panel of suitable consultants from which ACAP may choose. ACAP will refer the list to CODE for comment before acting.

A.3. Examine and comment on pro formae to be used for the gathering of information on current, past and future programmes as described in paragraph B.1.

A.4. Examine and comment to ACAP on the adequacy of the data collected on current and past strength. CODE will also be asked to comment on the data reliability.

A.5. Both in consultation with ACAP/CODE representatives and separately, consider the situation revealed by the tabulation of proposed future programmes and consider whether future plans should be modified or developed in more detail. As a result of this step, individual universities may wish to revise the material described in B.1.d below.

A.6. Possibly develop a tentative plan for development of established or new doctoral work in Ontario paying attention to adequate coverage of fields and specialties. Any such plans will be reported to ACAP which will transmit them to the consultants and to CODE.

A.7. For this assessment, the discipline group shall consist of a member of each of the Departments of Electrical Engineering, that member being the chairman unless the chairman delegates this responsibility to a colleague on a permanent basis.

B. Information from Universities

B.1. Each university is asked to supply to ACAP, in the form indicated by ACAP after comment by CODE and by the discipline group (paragraph A.3.).

information as follows:

a) for each specialty field determined in A.1.

(i) current list of faculty members showing fraction of research and graduate instruction time devoted to the field (for part-time professors show the time spent on university duties);

(ii) numbers of full-time and part-time faculty members for each of the past five years;

(iii) for the current year and preceding five years, number of (1) master's and (2) Ph.D. candidates and (3) post-doctoral fellows doing research in the field full and part-time shown separately.

Under these three headings one individual may appear under more than one category.

b) for each "<u>department</u>" which offers doctoral work in the fields of this assessment

(i) Curricula Vitarum of each faculty member (Assistant Professors and higher) showing inter alia complete publication lists, research funding in the past five years, and graduate students and post-doctoral fellows supervised during his career, and specialization.

(ii) resources of space - a statement indicating the department's view of the adequacy of its space, and, in connection with the future plans in (d) below, discussing future space provision;

(iii) number of Bachelors' graduates in electrical engineering and number of qualifying or make-up students each year for the last five years;

(iv) other general items relevant to research and graduate study,
a) major laboratories and equipment, over $5,000
b) computing facilities;

(v) support from related departments including shared teaching and research;

(vi) description of any inter-university arrangements for graduate work.

c) table of characteristics of graduate students in the department in previous five years, separately for Master's and Ph.D., breaking down numbers by:

(i) Full-time and Part-time;

(ii) immigration status (3 years) and country of first degree;

(iii) sources of financial support;

(iv) time to reach degree;

(v) drop-out number;

(vi) degrees granted;

(vii) post graduate employment of Ph.D.'s
a) immediate and
b) after two years.

d) proposed plans for the future of doctoral work, in as much detail as the department can provide, including the proposed scheme for support of these plans, and accompanied by supporting arguments, including consideration of the sources of doctoral students and an analysis of demand for graudates from the programmes as indicated by previous placement experience. The various headings in a) and b) above should be dealt with quantitatively where possible; as a minimum, planned numbers of faculty and doctoral students should be given. If part-time doctoral work is contemplated, please discuss in detail.

B.2. The material so supplied will be collated by ACAP and transmitted to the discipline group for action indicated in paragraphs A.4., A.5 and A.6.

B.3. Apart from the material described in B.1.d. and to some extent generated at the department level, each interested university will be requested to make an individual statement on its plans for the development of doctoral work in these fields of engineering, in particular the items of future commitment implied by item B.1.d.

C. Terms of Reference of Consultants

C.1. Consider the two special documents related to the coordination of the assessments in Engineering, viz. Engineering Ph.D. Planning and Assessment Procedures, Statement on Ph.D. Studies in Engineering Studies in Ontario, and the material prepared by the discipline group and the universities and obtain other data they may require to carry out the tasks detailed below. They shall be provided with copies of "Ring of Iron", the COU statement thereon, and the CODE, OCGS and APEO responses. They may obtain data and views from any relevant source, such as, for example, employers of holders of graduate degrees, professional and learned societies, federal agencies. The campus of each interested university shall be visited by at least two consultants. Consultants shall arrange their schedule of visits to the universities in consultation with ACAP to ensure uniformity. Reports of appraisal consultants are privileged documents and are not to be made available to ACAP consultants. Consultants shall meet with the discipline group near the beginning of the work, during the work as they consider necessary, and immediately before preparing their final report.

C.2. Report on the adequacy of the present state of doctoral work in "electrical engineering" in the province in general and in each university where applicable, discussing the following:

a. coverage of fields and specialties, and extent of activity in each

b. faculty quality and quantity

c. nature of programmes offered

d. enrolment size and distribution amongst universities and divisions

e. quality of student body; admission requirements

f. relationship to related disciplines and to the profession

g. physical facilities

h. other matters considered by the consultants to be significant.

C.3. Make recommendations for the development of doctoral work in fields of this assessment in Ontario between 1973 and 1978, taking into consideration such plans as may be developed by the Discipline Group, and, without limiting the generality of the foregoing, dealing with the following points:

a. Desirable doctoral programmes to be offered in the province, considering both possible limitations or reductions of existing programmes and creation of new programmes and new kinds of programmes including the appropriateness of part-time programmes. In particular, consider if there should or should not be more activity in fields now producing few graduates in Ontario and also the desirability of developing further application-oriented and inter-disciplinary work and industrial involvement.

b. Desirable provincial enrolments, year by year, in the doctoral study in electrical engineering and in the major subject divisions where appropriate. One should consider the need for highly trained manpower and also the general cultural and societal factors which may lead students to pursue doctoral work in engineering. In considering manpower needs, one should take account of the "market" available to graduates (at least all of Canada) and of other sources of supply for that market. Results of forecasts of high level manpower employment should be treated with due caution and only in a clearly balanced relationship with cultural and societal needs.

c. Distribution amongst the universities of responsibility for programmes and for specialties where appropriate, including consideration of the need for any increase or decrease in the number of departments offering doctoral work and including consideration of areas of collaboration and sharing of facilities at regional level and across the province. Consider techniques for involvement in doctoral supervision of professors in departments which do not take doctoral students in their fields, and the extent to which such activity is desirable.

d. Distribution of enrolment amongst the universities, showing desirable ranges of enrolment.

In all cases, it is important that the rationale for the recommendations be clear; this is especially important for items c. and d.

C.4. It is permissible for consultants to recommend appraisals of individual programmes. This would arise if consultants were to suspect that a programme would be found to be wholly or in part below minimum acceptable standards; and appraisal by the Appraisals Committee is the means of settling the question. It is recognized that this action would be infrequent. In carrying out planning assessments in some disciplines, consultants find there to be an excess or deficiency of programmes in a given area of study, where all of the existing programmes could pass an appraisal, they may, subject to their own judgments of relative quality and of other factors (a task outside the terms of reference of the Appraisals Committee), recommend where enrolment should be changed in accordance with the possibilities indicated in section C3 (c).

D. Appointment of Consultants

The consultants shall include one person of wide academic experience in Canada but in a different discipline. The other two consultants shall be engineers of international standing, with suitable administrative and/or teaching experience, and with expertise in some of the fields assigned to the electrical engineering assessment.

E. Report of Consultants

The consultants submit a joint report to ACAP (tentative date of September 1973). Minority reports are, of course, possible. The reasoning leading to their recommendations should be given fully, in view of the subsequent treatment of the report. The report is submitted for comment to CODE, to the discipline group and to each interested university. There may be informal or interim exchanges of views amongst the discipline group, the universities, CODE and ACAP. Any university which wishes to make a formal statement to COU on the consultants' report shall submit it to ACAP. Any such report shall be transmitted to CODE and to the discipline group. The discipline group shall submit its formal comments and/or recommendations to ACAP and CODE. CODE submits to ACAP its recommendations to COU. ACAP considers the CODE, discipline group and university statements along with the consultants' report and transmits them to COU with its recommendations of the position COU should adopt. Copies of the material transmitted to COU will be supplied to CODE, to OCGS, to the members of the discipline group and to the interested universities. CODE, OCGS and the universities are thus enabled to prepare for direct comment to a COU meeting. The consultants' report may be published together with the comments of CODE, the discipline group and those of any university so requesting, and with the position adopted by COU.

Amended November 29, 1972.

Engineering Ph.D. Planning and

Assessment Procedures

Coordinating Task Force, September 25, 1972

1. The doctoral assessments in Engineering are being conducted as a group. To that end there has been established a Coordinating Task Force to coordinate the conduct of the assessments in accordance with the procedures outlined in this document which is referred to in section C1 of the Terms of Reference for the Consultants.

2. All "departments" of each Engineering Faculty shall prepare a statement presenting their current and proposed Ph.D. activities including:

   (a) areas of research and study
   (b) educational goals and style
   (c) enrolment ranges projected to five years, and other items as defined in section B of the approved "Procedure", including the basic ACAP quantitative data sheets as modified for the engineering assessments.

   The quantitative data sheets, to be submitted to ACAP by November 1, 1972, and the "five-year plans", due by the end of January 1973, will then be distributed by ACAP to the discipline groups for consideration and planning action by the individual institutions and by the discipline groups. Copies will be made available to the members of CODE.

   Departments are encouraged to discuss their preliminary plans with the appropriate discipline group prior to formal submission in January and the discipline groups should be active in their planning function throughout this period.

3. Each Discipline Group will be charged to prepare from the statements a report on Ph.D. activities and plans in their discipline area, noting both apparent conflicts and gaps in both areas of specialization and enrolments. Reports will be distributed as above, by the end of February 1973.

4. Each University may modify the above statements in the light of the above and in consultation with the Discipline Groups and other Universities as appropriate. Subsequently the Discipline Groups will finalize their reports, which are due to ACAP by April 15, 1973.

5. These statements and reports, along with the regular ACAP assessment data (to be prepared during the above process, perhaps with CODE "data bank" collaboration) shall form the data base for the assessment teams. Failure to meet deadlines will not be allowed to delay proceedings.

5. The Coordinating Task Force will review the detailed terms of reference to be given to the consultant teams, particularly in the educational professional areas. This is scheduled for completion by September 30, 1972.

6. Upon completion of (4) above, the Coordinating Task Force shall recommend to CODE and ACAP whether areas in Engineering not clearly included within the five major discipline areas shall be included within the total of engineering activity without further review, or included within one or more of the major discipline studies, or be subject to a small special assessment process.

7. CODE, with assistance from COU and utilizing outside expertise as needed, shall implement a special study of the engineering manpower situation at the Ph.D. level. This study should be available for consideration by ACAP, the Discipline Groups and the consultants prior to the drafting of final reports and responses. Reports on the progress of this study shall be reviewed by the Coordinating Task Force; the first report shall be due by the end of 1972.

8. The formal assessment and consultative process shall commence on completion of (4) and the consultants shall be provided with a general statement, in addition to the data base material, terms of reference, and other relevant documents. This statement which has been prepared by the Coordinating Task Force and is referred to in section C1 of the Terms of Reference for the consultants is intended to draw attention to some features of the Ph.D. in Engineering which the Task Force considers distinctive enough to merit particular consideration by the consultants. Educational, professional and research concerns will be emphasized. Briefings and discussions with ACAP and the appropriate Discipline Group will complete the first stage of this process. These discussions are expected to occur about one month prior to the first visits and the visits themselves will be concentrated in the month of May and June.

9. The next stage consists of consideration of the available material by the consultants, University visits, meetings with the Discipline Group, and the preparation of a draft report by September 1, 1973.

10. The draft reports will be made available to the Engineering Deans and to the Discipline Groups to provide for initial feedback to the consultants. There will be oral response from the Discipline Groups to the consultants. Following this the consultants will draft their final reports which will be followed by official responses from the above groups and finally by consideration by COU. (The above is intended to make clear that while feedback to the consultants from the Discipline Groups is desired and expected, the draft reports are not to be distributed for open discussions within departments.)

A P P E N D I X E

DISCIPLINE GROUP MEMBERSHIP

APPENDIX E

DISCIPLINE GROUP MEMBERSHIP

CARLETON -	A.R. Boothroyd (2 representatives) J.S. Riordan
McMASTER -	S.S. Haykin, until July 1, 1972 E. della Torre
OTTAWA -	C. Lemyre
*QUEEN'S -	C.H.R. Campling
TORONTO -	G.R. Slemon
WATERLOO -	K.D. Srivastava
WESTERN -	I.I. Inculet
WINDSOR -	E. Kuffel

*Chairman of Discipline Group

APPENDIX F

ROLES OF ACAP AND OF DISCIPLINE GROUPS

Ontario Council on Graduate Studies

By-Law No. 3

A By-Law to establish a Committee on the Academic Planning of Graduate Studies.

1. The Ontario Council on Graduate Studies, recognizing the importance of providing for the continued and orderly development of graduate studies in the Ontario universities, establishes a Standing Committee to be known as the Advisory Committee on Academic Planning (abbreviation - ACAP).

Interpretation

2. In this By-Law,

(a) "Committee" without further specification, means the Advisory Committee on Academic Planning;

(b) "Council" or OCGS means the Ontario Council on Graduate Studies;

(c) "Committee of Presidents" or CPUO means the Committee of Presidents of Universities of Ontario;

(d) "university" means a provincially assisted university in Ontario;

(e) "discipline" means any branch or combination of branches of learning so designated;

(f) "discipline group" means a body designated as such by the Committee of Presidents of the Universities of Ontario, and normally consisting, for any one discipline, of one representative from each of the interested universities;

(g) "planning assessment" means a formal review of current and projected graduate programmes within a discipline or a group of disciplines;

(h) "programme" signifies all aspects of a particular graduate undertaking;

(i) "rationalization" means the arranging of graduate programmes in order to avoid undesirable duplication, eliminate waste, and enhance and sustain quality.

Membership

3. (a) The Committee shall consist of at least seven members of the professoriate in Ontario universities, some of whom shall be members of the Council.

(b) The members of the Committee shall serve for such periods of time as the Council may determine, and they shall be selected in such manner as may provide for reasonable balance both of academic disciplines and of universities

(c) The members of the Committee shall be appointed as individuals.

Chairman

4. The Chairman of the Committee shall be named by the Council, and he shall have one vote.

Quorum

5. A majority of all members of the Committee shall constitute a quorum.

Functions

6. The functions of the committee shall be

(a) To advise OCGS on steps to be taken to implement effective provincial planning of graduate development;

(b) To promote the rationalization of graduate studies within the universities, in cooperation with the discipline groups;

(c) To recommend, through OCGS, to CPUO the carrying out of planning assessments of disciplines or groups of disciplines and to recommend suitable arrangements and procedures for each assessment;

(d) To supervise the conduct of each planning assessment approved by CPUO;

(e) To respond to requests by CPUO to have a discipline assessment conducted by proposing suitable arrangements;

(f) To submit to CPUO the reports of the assessments together with any recommendations which the committee wishes to make. A copy of the report shall be sent to Council.

Jurisdiction

7. In order that the Committee may discharge the functions described in Section 6 above, it shall be authorized

(a) to request a university to provide such information pertaining to graduate studies as may enable the Committee to discharge its functions;

(b) to request a discipline group to provide such information as may enable the Committee to discharge its functions;

(c) to receive reports from the universities and from the discipline groups, and to comment and communicate with the universities and the discipline groups concerning such reports;

(d) to convene a meeting of any discipline group for the purpose of discussing the development to date, and proposals for the future development of graduate studies in the discipline concerned;

(e) to send one or more representatives to a meeting of a discipline group at the invitation of the discipline group;

(f) to make such suggestions to a discipline group as may be deemed appropriate to the functions of the Committee;

(g) to supervise the conduct of planning assessments, and to report thereon to the Committee of Presidents of Universities of Ontario;

(h) generally to report and to make recommendations to the Council;

(i) to seek and receive advice from appropriate experts;

(j) to employ consultants in connection with planning assessments;

Procedures

8. The procedure to be followed by the Committee shall be as approved by the Committee of Presidents of the Universities of Ontario.

9. The Committee's function is solely advisory.

Effective Date

10. This By-Law shall take effect January 1971.

ACAP DISCIPLINE GROUPS AND THEIR ROLES

1. Establishment of a Group

a. When it is considered desirable to activate planning of graduate work in some discipline(s) or interdisciplinary area, COU, on the advice of OCGS, will authorize the establishment of an ACAP discipline group, if it was not already approved and included in the May, 1968 list. If it is already authorized, ACAP may decide to set it up as described in paragraph b.

b. The Executive Vice-Chairman of ACAP will then invite the executive head of each university (including Waterloo Lutheran) either to nominate a member of the discipline group or to indicate that his university has no plans for graduate study in this discipline in the next five years or so. If a university can state no plans for future graduate work in the subject, but feels that a watching brief is desirable, it may appoint an observer to the group.

c. Changes of a university's representative are to be notified by the executive head.

d. The group shall select its own chairman.

2. Meetings

a. A discipline group may meet at the call of its chairman or in accord with its own arrangements.

b. A discipline group may be called to meet by the Executive Vice-Chairman acting for ACAP.

3. Responsibilities

a. The group is to keep under review the plans for graduate work in its discipline in Ontario, including new developments and trends in the discipline, and to make reports to ACAP on a regular basis.

b. The group may make recommendations to ACAP in connection with graduate work in its discipline when it considers it appropriate.

c. ACAP will assist the group in obtaining information and data, as mutually agreed.

d. When COU has instructed ACAP to conduct a planning assessment, the discipline group will assist and advise ACAP in determining procedures and terms of reference, will report as requested and will generally facilitate the assessment.

Approved by OCGS March 22, 1973
and by COU April 6, 1973.

A P P E N D I X   G

CURRICULA VITARUM OF THE CONSULTANTS

MORREL P. BACHYNSKI

Born Bienfait, Saskatchewan, July 19, 1930

B.Eng., Saskatchewan, 1952
M.Sc., Saskatchewan, 1953
Ph.D., McGill, 1955

R.C.A. Research Laboratories, 1955; Director of the Microwave and Plasma Physics Laboratories, 1958-65; Director of Research, 1965-

Fellow of the Royal Society of Canada
Fellow of the American Physical Society
Fellow of the Canadian Aeronautics and Space Institute
Associate Fellow of the American Institute of Aeronautics and Astronautics
Senior Member of the Institute of Electrical and Electronics Engineers
Member, Professional Group on Antennas and Propagation
Member, American Geophysical Union
Member, Canadian Association of Physicists, President 1968-69
Member, Canadian Research Management Association

Vice-President, SCITEC
Chairman, NRC Associate Committee on Plasma Physics
Member, Editorial Advisory Board of Science Forum

Electromagnetic wave propagation; microwave and plasma physics

Address: Research and Development
RCA Limited
Research Laboratories
Government and Commercial Systems Divisions
Ste. Anne de Bellevue
Quebec.

ARTHUR DONALD MOORE

Born Assiniboia, Saskatchewan, April 28, 1923

B.Sc., Queen's, 1945
M.Sc., Queen's, 1950
Ph.D., Stanford, 1953

Turbo Research Ltd., Ontario and Power Jets Ltd., England,
Junior Engineer, 1945-46
Avro Canada, Junior Design Engineer, Gas Turbine Division, 1946-47
Queen's University, Instructor, 1947-49
University of British Columbia, Instructor, 1949-50
University of British Columbia, Assistant Professor, 1952-55
Associate Professor, 1955-61
Professor, 1961-
Head of Department, 1970-

Member, American Society of Engineering Education
Senior Member, Institute of Electrical and Electronics Engineers

N.R.C. Senior Research Fellow, 1964-65
Electrical Engineering Grant Selection Committee, National Research Council, 1967-69
Chairman, Board of Examiners of the B.C. Association of Professional Engineers, 1961-62
Canadian Accreditation Board, Canadian Council of Professional Engineers, 1972-

Network theory; electronic instrumentation; computer-aided design

Address: Department of Electrical Engineering
University of British Columbia
Vancouver 8, B.C.

MAC ELWYN VAN VALKENBURG

Born Union, Utah, October 5, 1921

B.S.E.E., Utah, 1943
M.S., Massachusetts Institute of Technology, 1946
Ph.D., Stanford, 1952

University of Utah, Instructor, 1946-48
    Assistant Professor, 1948-49
Stanford University, Acting Instructor, 1949-51
University of Utah, Associate Professor, 1951-55
University of Illinois (Urbana), Associate Professor, 1955-56
    Professor, 1957-66
    Associate Director, Coordinated Science Laboratory, 1959-66
Princeton, Professor and Chairman, 1966-

Fellow, former Vice-President, of the Institute of Electrical and Electronics Engineers
Member, International Scientific Radio Union
Member, American Society for Engineering Education

Westinghouse Award, American Society for Engineering Education, 1963
Education Medal, IEEE, 1972

Circuit theory; applications of graph theory; systems engineering; energy conversion and resources

Address: Department of Electrical Engineering
Princeton University
Princeton, New Jersey
08540

APPENDIX H

RESPONSE OF THE COMMITTEE OF ONTARIO DEANS OF ENGINEERING

COMMITTEE OF ONTARIO DEANS OF ENGINEERING

RESPONSE TO ENGINEERING PhD ASSESSMENTS

Preamble

Individual reports of PhD Assessments have already been received by discipline groups and by individual universities. Both bodies will undoubtedly make detailed commentary on the specific reports which are of direct concern or interest. In view of this, CODE has decided to forego comment on such specifics, and has determined to refer only to those matters of a more general nature which affect the universities collectively. In choosing to frame its response in unitary fashion, CODE wishes, at the outset, to emphasize that it views engineering education and practice as a total activity instead of a discrete set of unrelated disciplines such as Chemical, Civil, Electrical, Materials, Mechanical and Metallurgy, etc. This theme of relationships between disciplines within a faculty, and indeed between faculties, will recur later in the report in subsequent discussions.

Of the ten topics on which CODE sets out its 'responses', three are considered to be of primary importance - manpower, quality, and critical size. Consequently, they have been covered in somewhat greater detail than have other topics of interest, in order to provide identification and emphasis, rather than a fully developed 'position'.

The primary concern in this response is unquestionably that of quality over quantity. In assuming this position CODE realizes that the indicators of quality are undoubtedly staff, students, programmes and facilities. It is difficult to assess the precise hierarchy of these four basic parameters. Suffice it to say that, while the first two are paramount in terms of establishing potential for excellence, the last two are important in realizing this excellence.

CODE offers its resources in such further and subsequent amplification as may be useful to the purposes of the Council of Ontario Universities.

Manpower

CODE is in agreement with the general observations of the consultants with respect to the PhD manpower situation. It appears clear that the supply of PhD candidates will be limited by the availability of high quality entrants. The relatively small numbers of Canadian graduates entering PhD programmes is a cause for concern. If Canada is to advance industrially, it would be expected that there would be an increasing demand for high-technology support. An under-supply of PhD graduates in engineering would not be in the best interest of society. There is clearly no evidence of any over-supply because of the way engineering graduates at all levels are seen to diffuse widely through industry, commerce and government; there appears no prospect of this becoming a problem in the future.

CODE realizes the importance of maintaining up-to-date knowledge of positions taken by the PhD graduates of the Ontario Engineering schools and intends to ensure that such information is updated annually. A copy of a recent survey is included as part of this response. It will be noted from this survey that there has been a shift in the area of employment of engineering PhD's towards industry.

In the light of the consultants' analyses, and of the appended data, there is no need for quotas or ceilings on doctoral students. CODE will continue to report on the number and origins of doctoral students in the various engineering schools, on an annual basis.

Quality Emphasis

(a) Admission

CODE is pleased to note that the consultants have agreed that high admission standards to engineering doctoral programmes generally prevail.

CODE, therefore, supports the contention that existing minimum entrance standards to PhD programmes should be maintained across the Province. CODE believes that a post facto analysis of admission practices, widely publicized, will be adequate to ensure this objective.

In application of these standards, it must also be acknowledged that certain defensible exceptions will occur with respect to those with known special abilities or those who have demonstrated superior ability in research, design and innovation in their post-baccalaureate experience.

CODE fully supports the view of the electrical consultants that it is "in Canada's interest, especially in international competition, to have strength in high-technology research and development" and for this to happen there must be an objective of "high standards of excellence with emphasis on quality".

(b) Programmes and Faculty Facilities

CODE recommends that totally independent and representative bodies continue to oversee negotiated development grants and the formation of centres of excellence. These are matters better left outside the jurisdiction of such a body as CODE.

(c) Undergraduate/Graduate Programme Relationship

CODE supports the contention that the continued existence of a live, up-to-date undergraduate programme requires the backing of a good research programme and participation in professional practice by members of the faculty. The research activity, in the prevailing tradition, is most easily met through the provision of Master's and PhD postgraduate programmes.

(d) Quality Indicators

In addition to the observance of university regulations, and the use of high calibre external examiners, the observed career performance of doctoral graduates can be used as a 'quality indicator'.

Critical Size for Doctoral Programmes

In order to be viable, a PhD programme must provide a sufficient range of interaction for the student. He must be exposed to enough faculty members and enough other students to provide adequate breadth of experience and instruction. The adequacy of this breadth cannot be judged exclusively by the size of the department in which he is registered.

The ACAP assessments, by being completely vertical, miss the rich horizontal components which can and do nourish and sustain viable doctoral programmes in both small and large departments and faculties. Resources from other divisions of the university, other engineering departments, industry and, indeed, other engineering faculties must be considered in any realistic analysis of PhD programme viability.

Size is not a sufficient criterion for judging whether a school can offer a PhD programme; there is no *a priori* reason why a small school cannot provide as satisfactory an environment for the student as can a large school.

Engineering in the Wider Context

CODE would draw attention to the need to view the totality of the PhD programmes in engineering not just in isolation, but also in the context of other related disciplines; e.g. physical, life and social sciences.

To progress technologically in such a way as to improve the quality of life not only in Canada but also in other parts of the world, it is essential that there be work proceeding concurrently in the forefront of various other disciplines which impact on engineering. It is anticipated that increasingly advanced work in various areas will need to proceed in a more integrated fashion and it will be essential to have available high level manpower in the physical, life and social sciences, economics, and management, for instance, together with similar capabilities in engineering.

Research Emphasis and Relevance

As a result of the ACAP Engineering Assessments, there is now readily available information about research projects underway in all the Ontario

Engineering Schools. The system would have profited more had the consultants commented in detail on this information and offered substantiated specific advice on the topics of emphasis and relevance.

CODE feels that PhD programmes in engineering should be flexible enough to cover a broad range of topics. Research activities could and should range from mission-oriented research of an immediate and perceived social or industrial relevance through to very fundamental or basic research. The overall thrust of PhD research programmes should be towards advancing fundamental engineering knowledge required for the solution of present and future engineering problems.

CODE also feels that a plurality of sources of research support is a relatively effective means of ensuring that a broad spectrum of research activity is undertaken within the engineering schools. The existence of a variety of granting bodies, with a spectrum of interests represented, including a significant academic component, appears to be an effective method of control.

Level of Support for Doctoral Students

CODE strongly supports the contention that levels of support for doctoral students must be increased substantially if more Canadian students are to be attracted to entering doctoral programmes in engineering.

It should be noted that foreign graduate students have been willing to undertake PhD studies at the levels of support available and have subsequently filled positions within Canada. Positions have been available for PhD's - these have been filled largely by landed immigrants who have either completed PhD study in Canada or who have come to Canada with a PhD.

The recent increases in both the cost of living and salaries offered by industry to engineering graduates makes it even more urgent that immediate action be taken to increase the support for doctoral students. This is particularly true if post-baccalaureate experience students are to be attracted. Therefore, it is important that more opportunities be available for this particular type of doctoral student in engineering.

Part-Time/Non-Resident Work

CODE would encourage continued experimentation in this regard. It is felt that maintenance of some institutional contact is essential, however. It is felt further that any part-time or non-resident work should normally be by individual arrangement. This would not, of course, preclude special arrangements between a research institution or industry/government laboratories and a particular university or universities.

Inter-University Activities and Facilitating Mechanisms

CODE would support any action designed to increase the effectiveness of the provincial resources in faculties of engineering. The holding of discipline meetings, the sharing of equipment, interchange of credits for graduate courses, collaboration between groups within various institutions and so on are to be encouraged. It is emphasized that co-operation often involves travel and other expenses that are not always readily available in individual schools and that this matter is worthy of further investigation.

It is noted that inter-university activity is proceeding especially at the 'grass-roots' level and this can be aided and abetted by CODE. It is also noted that various university industrial research institutes and similar agencies have facilitated some inter-university cooperation largely through use of individual expertise existing at various institutions.

The Role of the PhD in Entrepreneurship

CODE feels that entrepreneurial activity by PhD's is something which cannot be legislated. However, it feels further that the PhD has, by virtue of his total background, significantly greater potential for success in such activity than has the member of the general populace. It suggests that there are two avenues of encouragement which can lead PhD's in greater numbers into entrepreneurship. The first depends on the educational institution itself, which must, by appropriate orientation and emphasis, develop an interest in or leaning towards innovation, independent practice, or entrepreneurship. The second depends on progressive government support programmes of various kinds, directed to reaching a 'climate' competitive with that found in other industrial economies of comparable size.

Cost-Benefit of the ACAP Studies

CODE has noted that no major measures are proposed that would greatly enhance the quality of the PhD effort in Ontario. Indeed, CODE records its pleasure at the broad and independent affirmation of the consultants as to the strengths and qualities which have developed in Ontario PhD programmes.

The full programme of ACAP studies is as yet incomplete. CODE has yet to be convinced that the extensive funds and efforts devoted to the studies would not have been better spent in direct support of existing PhD programmes in engineering.

ANS/dd
December 27, 1973

APPENDIX A

REPORT ON THE CODE ENGINEERING DOCTORATE EMPLOYMENT SITUATION, OCTOBER 1973

In November 1973, members of the Committee of Deans of Engineering of the Province of Ontario again supplied data on the status of their engineering PhD graduates during the period November 1972 until October 1973. The results are compared in Table 1 with those for 1972.

Again this year, the majority of the graduates were in Chemical, Civil, Electrical and Mechanical Engineering. The total is up substantially to 177 from 124 in 1972.

Unemployment is up from one in 1972 to three in 1973 (approximately 1.7% of the total).

Approximately 17% have left Canada, which is the same as for previous years and is probably due to the return of foreign students to their home countries.

A notable increase in employment in industry has occurred, up to 33% from 21% in 1972. The number employed in Canadian universities is up to 26% from 21% in 1972. This has been accompanied by a decrease in post-doctoral fellowships from 23% to 11%.

The overall conclusion is that there is still no serious unemployment among recent Ontario PhD graduates in Engineering despite predictions to the contrary. In fact, a healthy trend toward their increased utilization in Canadian Industry may have been established.

December 13, 1973.

ONTARIO ENGINEERING PH.D EMPLOYMENT SURVEY 1973

The employment status of one hundred and ninety-two graduates with PhDs in engineering from Ontario universities during the period November 72 to October 73 was determined in November 1973.

ENGINEERING DEPARTMENT OR DISCIPLINE	Unemployed		No professional Employment		Employed in Industry		Employed in Government		Employed in Universities		Postdoctoral Fellowships		Have left Canada		Unknown		TOTALS	
	1972	1973	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73
Aero/Space	-	-	-	-	1	3	-	-	1	3	4	1	-	-	-	-	6	7
Bio-Medical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Chemical	-	1	-	-	4	13	1	3	7	5	7	5	3	2	4	2	26	31
Civil	-	1	-	-	5	7	2	5	3	14	6	5	9	7	5	-	30	39
Electrical	-	-	2	-	9	20	3	2	5	11	7	5	4	9	1	-	31	47
Industrial	-	-	-	-	2	-	1	-	2	-	-	-	-	-	-	-	5	0
Materials/Metals	-	1	-	-	1	6	1	-	1	3	2	2	-	3	-	-	5	15
Management	-	-	-	1	-	-	-	-	1	1	-	-	-	1	-	-	1	3
Mechanical	1	-	-	-	4	9	2	5	6	8	1	1	2	7	2	1	18	31
Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Physics/Science	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2	0
Systems Design	-	-	-	-	-	-	-	1	-	1	-	-	-	2	-	1	0	4
TOTALS	1	3	2	1	26	58	10	16	26	46	28	19	19	31	12	4	124	177

APPENDIX B

Comments on CEMC Report

"Supply and Demand for Engineering Doctorates in Canada" (July 1973)

Submitted by the Committee of Ontario Deans of Engineering

Commendation of this report can be made in a general sense on two main scores. Firstly, the consultants have, on assignment, tackled in a straightforward manner, what is generally acknowledged to be a most difficult task indeed; where qualitatively it is not possible to assert all possible parameters, and quantitatively, it is not possible to obtain reliable data on all accepted parameters.

Secondly, the consultants have in their report introduced with some care statements relating to the qualifications and limitations of the many elements entering into their predictions, and have emphasized that this is only a beginning - ergo, a very preliminary report.

Within this general context, however, there are a number of criticisms to be advanced.

1. <u>Supply</u>

The methodology has been clearly enunciated, and the assumptions stated. Nonetheless, projections have been made on a three-level approach (high, medium and low), establishing bounds which may well be broken as and when certain assumptions become less or more operative. Some indicators are already present as to the dangers of some of the assumptions.

1.1 Admission requirements are not static, and are increasingly adaptable to the changes in the high school. Three other important aspects must be added. There is, firstly, foundation for expecting a major growth in the number of women entering engineering. Secondly, the "market-place" reaction with a rapid response in the 1st year enrolment to a proclaimed shortage in engineers will continue to be operative. Thirdly, there is further indication that advanced admissions (through the stop-outs returning, through technology graduates admissions, etc.) are increasingly important in enrolment projections. None of these has been clearly taken into account in this report. A further aspect could well be added, which is also ignored in the report, but is less easy to define though it will contribute to the instability in prediction of 1st year enrolment. This relates to measuring the full impact of major educational changes on the Canadian scene. The effect of the CEGEP's in Quebec in particular, as well as of the CAAT's in Ontario, is yet to be clearly perceived, let alone settled into a measurable or stable influence.

1.2 The two data bases selected for examination were the number of master's degrees and the number of baccalaureates. The discarding of the master's degrees/doctorate degrees ratio as credible seems to ignore the very recent development of many doctorate programmes as contributing to a rapid change in this ratio. The total postgraduate effort in engineering in Canada is of such an emerging character that rates of change must be evaluated much more carefully. This is equally true for the baccalaureate/doctoral ratio selected as a data base. The evidence for stabilization in this is slight, and even the selection of three ratio levels is likely subject to major error through neglect of variable factors in an easily perturbed system. The changing pattern in the number of Canadian baccalaureates who earn doctorates outside the country is one further feature of a system which as yet has little maturity or stability in it. This aspect of immigration was noted in the resport as one for which no data was available - which ignores one fully-documented part of the system, the Athlone Fellows.

1.3 The utilization of the baccalaureate/doctoral ratio as a data base for predicting future supply has another feature which is inadequately considered and analysed. This relates to the forces which are operative on graduates of Canadian engineering schools vis-a-vis their proceeding to doctoral work. Graduates of the engineering schools of Canadian universities have never come forward in substantial numbers to undertake advanced study and research. The tradition of such a choice, and indeed the number of opportunities for such advanced work, are relatively new on the Canadian scene. The expansion of the graduate schools over the past decade has been effected therefore by the attracting of students with overseas degrees, particularly from Asia. Many of these students from overseas have been or have become landed immigrants, have stayed in Canada and have taken jobs as PhD's. These jobs have been available, they have not been taken up by Canadians who seem to have preferred to enter the work-force earlier, immediately after obtaining the bachelor degree. There are probably many factors which have conditioned the particular choices of Canadian engineering graduates at the bachelor level, but primarily it is probably a combination of (a) the fact that they have been so readily absorbed into the economy at that level, and (b) the fact that the level of financial support available for graduate study has been too low to make them feel that the sacrifice is worth it. For the near future, unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline. At the same time as the graduate schools in engineering become increasingly well established and recognized, and as high technology factors including its encouragement through government policies increasingly become operative, the opposite effect could well occur. The imprecision therefore in assuming a stabilized bachelor/doctoral ratio is greater than assumed in the CEMC study.

1.4 In the consideration of the report, moreover, one should not perhaps overlook the possible impact of events occurring in other jurisdictions. The report suggests that the annual number of bachelor degree graduates will fall from about 4,500 to 3,000 over the next three years, with most of this decrease due to a falling-off in freshmen enrolments in provinces other than Ontario. This could suggest in itself a likelihood of fewer qualified Canadian graduates available for PhD studies at our universities. This must be viewed in conjunction with the situation in the U.S. where undergraduate enrolments in engineering have fallen very sharply over the last few years and this will lead to a very substantial decrease in the number of bachelor engineering degree graduates over the next few years. The combined Canada/U.S. graduating class was about 47,000 in 1971. It will be only about 35,000 in 1975. One might wonder whether, because of excellent opportunities at the bachelor level, a smaller proportion might proceed to PhD work or conversely whether the lack of anxiety about employment prospects at the bachelor level will give more students the confidence to continue with their studies.

1.5 A further major criticism of this part of the report rests not on the methodology, elements of which have been discussed above, but on the basic data used in the calculation steps. Without examination of each and every set of data used, it can nonetheless be indicated that the rather complex combinations of undergraduate enrolment and graduation data from Statistics Canada, from EIC enumerations, from the "Ring of Iron" for Ontario leave some inconsistencies. The number of bachelor's graduations and of doctorates were obtained only to 1970-71, while the number of master's degrees were recorded for 1971-72. In view of the rapid build-up in Canada of doctorate degrees (from 78 in 1965-66 to 216 in 1970-71) it would have seemed to be quite important to establish the 1971-72 figures before final projections were carried out. In view of the prominent place taken by the Ontario system contribution it is indeed surprising that more current data at hand in COU (ACAP) was not utilized. Nonetheless, it is fair to point out that the actual doctorates in Ontario for 1972 and 1973 respectively were 124 and 177, and that the former figure compares to the low level projection for 1971-72 of 126, and the latter to the high level projection of 172 for 1972-73. At least the projection band width used just encompasses the first stages of comparative actual data.

2. Demand

The report includes a comprehensive survey of manpower demand methods, and a careful statement of the method followed for each of the sectors explored, as well as its limitations. This demand aspect of the report is the one which has received the most criticism from the ACAP consultants in the five engineering fields assessed. Our criticisms encompass the major elements of those comments in summary form as well as those voiced by the engineering schools in Ontario.

2.1 Educational Sector

The consultants' use of a model for the estimation of future demand in the educational sector is deceptively attractive. Essentially, their model was based on a staff-student ratio as a base, adjusted for retirement, mortality and migration. They concluded that to 1977-78 (at least) the demand for engineering doctorates would be essentially zero, and then admitted "this will not prove to be an accurate scenario". They then rest their case that in both universities and other educational institutions, the demand will be "minimal". In the dictionary sense of the least attainable or extremely minute in size, it is difficult to read into this other than essentially no demand. Even though rather elegantly derived, we find it hard to accept such a conclusion, particularly when the Ontario system itself projects now a demand for about 20 for 1974. Some of the parameters which would be omitted by the model used include increased demand through major block research grants, through mission-oriented research, and through the development of new programmes and areas. The report does deal at length with the question of "substitutability between inputs", but does not weigh it to the level where it would not be balanced by other factors. This question of substitution will also be referred to below in considering the total demand-supply picture.

2.2 Government and Industry Sectors

In these sectors the consultants chose to establish stock data and forecast demand for 1974, 1975 and 1978 by direct survey. From the many criticisms and indeed specific refutations that can be made, it is clear that this survey has been far too narrowly cast. In the government area this is certainly true regarding the narrowness of definition used. In the industry area it includes not only that limiting factor, but became subject to both incomplete data through using wrong sources, and through important omissions. To some degree the consultants were well aware of these deficiencies, but were obviously more conscious of them for the forecast demand data than for the stock data - where equally gross errors and omissions seem to have occurred. One example of such an error is in the stock of 52 in 1973 attributed to AECL, compared to the 90 actual in 1973 as provided by the Metallurgical engineering consultants in their report to ACAP. Other reports to ACAP specify other examples.

It is hard to escape the conclusion that the inadequacies of the demand survey are far greater than the consultants envisioned, and their errors of omission are much greater than they estimated.

3. General

3.1 Educational Planning and Manpower

What appears to be a basic premise of the report as contained in paragraph 1 on page (1) deserves comment, viz., "Now, a generally accepted view is that the expected labour market for graduates of a particular speciality should influence policy and planning in post-secondary education in that area."

This view may not be as generally accepted as one might be led to believe. The particular philosophy outlined can, taken to extremes, result in a shortsighted and constrained view of a university. It could well be argued that too marked a distinction has been drawn between what is educational and what is vocational. Recently this has been convincingly stated to be one of the major misconceptions in higher education planning*. The danger in assuming that all but preparation of people for specific jobs is wrong or wasteful is not just in the short-sighted effort to establish a one-to-one relationship between education and jobs. Rather it omits the important fact that vocationally oriented education is not wasted if it is not used in the specific vocation toward which it was directed. As Bowen* states, "It is no mark of failure, rather a mark of success, that education - even strictly vocational education - has wide applicability and produces flexible and versatile people". The PhD graduate even if he takes a vocational route initially may well very soon find himself in positions where his PhD can be regarded only as part of his general education or as a contributing factor to his intellectual development or problem-solving ability. It is not difficult to give examples of this "diffusion" of PhD's through a "vocational" period to positions of quite different responsibilities in industry, governments and the universities. The consultants gave careful attention at one stage in their report to this "diffusion" or dispersion, referring properly to the recent University of Toronto study. However, they did not then "factor" it in to either their supply or their demand projections. In our view, significant allowance should be made for it. On the supply side, both into the baccalaureate stream as well as into the doctoral stream in engineering the vocational/educational issue is not clear-cut nor should it be. On the demand side, there must be allowance made both for the substitutability through flexibility even at initial employment levels, and for increasing mobility and transfer into wider areas such as management as experience accrues. The difficulty of quantifying this is well appreciated. The need for including it in some definitive way demands equal appreciation.

3.2 The Supply and Demand Balance

The report in its final results and conclusions comes down strongly on the prediction of an oversupply of engineering PhD's in the decade ahead. They acknowledge a range of factors which will influence both their supply band projection and their demand band projection, including the possible effect of their own report. We acknowledge this danger and can only hope that it can be minimized by vigorous emphasis both

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* H. R. Bowen, "The manpower vs. the free-choice principle", University Affairs, Jan. 1974.

on the limitations of the report's projections but also on the countering evidence as it accumulates. We have indicated some of the aspects of both the supply and the demand projections which can invalidate the narrowness of the band widths selected. Perhaps more importantly in the long run is the real failure of any demand projection to be able to take into account any but the very short-term skill requirements of the economy. The evidence is quite clear that our society has an enormous amount of work to be done with a lack of sufficient skilled manpower to do it. We would claim that the adaptability of doctoral graduates in general combined with the adaptability of our economy results in a surprisingly good balance. The Ontario experience, well documented now for four years, indicates essentially no unemployment of engineering doctorates, no unusual hold-up or storage in a post-doctoral form, and changing flows into government and industry as demand from the universities slacken. The acceptance of a current balance, which does exist (with some evidence indeed of unfilled needs in some areas), could well be the starting point for the report's projections. The graphical summary given on page 18 would then present an entirely different picture.

We should rise above our national tendency to be cautious and pessimistic, recognize that even a PhD may be viewed as vocational or educational (hopefully both) according to the graduates perception of the market-place, alternative opportunities, his own desires and so on, and not deliberately cut back on PhD enrolments in engineering, especially on demand data of such doubtful validity as that contained in the CEMC preliminary report. We have so little to gain and so much to lose by taking such an approach. We need to display more optimism and confidence in ourselves and in the ability of highly educated manpower to seek out and create opportunities and to raise the level of some existing positions both in government and industry. It is to be hoped that our students also will display such optimism and take a broader view of the value of their education, and that this view is shared by our federal and provincial governments. We will need this spirit if we are to move into an era in Canadian industry where increasing sophistication and high technology become more and more necessary.

NOTES

Re: 1.1

Entrance to engineering was assumed constant on a demographic base, i.e. 0.5% of male population age 15 to 19; and assumed unchanged entrance requirements.

Re: 1.2 and 1.3

The greatest danger in assuming the validity of a stable B/D ratio for projection purposes resides in the fact that the doctorate figure for the last decade includes a very large but unknown number who did not come through the Canadian baccalaureate stream. The size of that group of doctorates was related largely to immigration policies (now changed and changing), to research grants policies (which have also changed), and possibly to more selective admission policies. Perhaps a meaningful B/D ratio could usefully be established when the D number arises almost entirely from the B stream. Such data have not been collected.